No. 2639 VOLUME 76 FRIDAY 9 OCTOBER 1959

FLIGHT

AIRCRAFT, SPACECRAFT, MISSILES

Official Organ of the Royal Aero Club First Aeronautical Weekly in the World Founded 1909

Editor-in-Chief
MAURICE A. SMITH D.F.C.

Editor
H. F. KING M.B.E.

Technical Editor
W. T. GUNSTON

Production Editor
ROY CASEY

IN THIS ISSUE

From All Quarters 346
The Anglo-American Conference 347
Missiles and Spaceflight 348
Straight and Level 350
Sport and Business 351
Air Commerce 352
Aviation Electronics Special Review 357-380
Jet Noise and Society 381
Jet-age Growing Pains 382
The Frontiers of Science 385

Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1; telephone Waterloo 3333. Telegrams Flightpres Sedist London. Annual subscriptions: Home £4 15s, Overseas £5. Canada and U.S.A. $15.00. Second Class Mail privileges authorized at New York, N.Y.

Branch Offices Coventry: 8-10 Corporation Street; telephone Coventry 25210. Birmingham: King Edward House, New Street, 2; telephone Midland 7191. Manchester: 260 Deansgate, 3; telephone Blackfriars 4412 or Deansgate 3595. Glasgow: 26B Renfield Street, C.2; telephone Central 1265.
New York, N.Y.: Thomas Skinner & Co. (Publishers) Ltd., 111 Broadway, 6; telephone Digby 9-1197.

© Iliffe & Sons Ltd., 1959. Permission to reproduce illustrations and letterpress can be granted only under written agreement. Brief extracts or comments may be made with due acknowledgement.

By-Passes and Fans . . .

A LETTER from Sir Frank Whittle on page 388 of this issue is a reminder that Great Britain has contributed more to world aviation than a practical system of jet propulsion. For it was Sir Frank himself (an engineer and visionary whose name will endure with those of Stephenson, Watt and Brunel) who initiated or inspired a whole range of gas turbine variants. Not least among these was a class that was first known as the ducted fan. But neither the unit nor its precisely descriptive name achieved ready acceptance, and it was not until a similar (double-flow) principle was revived by Rolls-Royce, under the denomination "by-pass," that an engine of this general character was put to work. Today, essentially the same powerplant is taking a lead in commercial flying as the "fan" engine, or turbofan. There is every indication, in fact, that it will establish itself as the standard prime mover for long-range subsonic passenger transports; yet, as Sir Frank remarks, the first of many patents relating to it is dated March 1936, and from 1942 onwards Power Jets were at work on a variety of schemes based on this very principle.

In the years between, the properties of the "fan" engine have received the most meagre recognition, and that academic. It was, we believe, Sir Arnold Hall, in his 1956 Wright Brothers Lecture, who first succeeded in drawing the attention of civil operators to its possibilities.

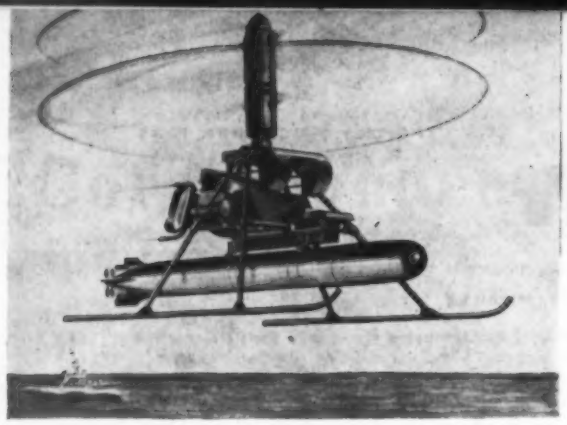
The first by-pass units installed in airliners were the Conways for the Douglas DC-8s of T.C.A. and the Boeing 707s of B.O.A.C. Only now, when these aircraft have put some flying behind them, can the true potential of these Anglo-American unions be appreciated. The 707's range is up by something like 600 miles.

. . . for Now and Tomorrow

In the transition to what might be termed full-blown fan engines Great Britain is backing up the Conway's lead. We remarked in our Farnborough review that both Rolls-Royce and Bristol Siddeley are developing families of entirely new powerplants operating on the double-flow principle. While these, as we say, are new, they nevertheless embody—without compromise—numerous components of earlier engines. Bristol Siddeley's BE.58 is matched to transports cruising at Mach numbers up to about 0.9; the RB.141 and RB.163 under development by Rolls-Royce are respectively intended for an advanced Caravelle and the Airco D.H.121. For the Vickers VC.10 an improved Conway is under development, having a lower cold-flow ratio than the new fan units, but nevertheless reconciling notably low consumption with the very high thrust (now disclosed as over 20,000 lb) demanded by B.O.A.C.'s 150-tonner.

Which is evidence that British manufacturers are out to maintain their status as aero-engine suppliers to the world. In that avocation they have earned over 260½ million pounds since the war. British engines are fitted in 55 types of foreign aircraft and America alone has adopted them for 19. Of over 1,400 turbine airliners on order or delivered (excluding the Soviet bloc) 874 have, or will have, British engines.

It is known that the S.B.A.C. would like to admit to Farnborough foreign aircraft with British powerplants, though the difficulty of accommodation has so far prevented this. But even so, there is more that can be done, come next Farnborough, to tell the resounding success-story of British aero engines in post-war years—a story with an opening (and now a footnote) by one Frank Whittle.



ANTI-SUBMARINE: Above is a sketch of the Gyrodyne DSN-1 drone for the U.S. Navy's first helicopter-carrying destroyer "Hazelwood." When a contact is made it is despatched by remote control to deliver its torpedo; then it returns. The Fairey Gannet AS.4 (right) is one of a batch, fully reconditioned and re-engined, for the Indonesian Navy

NA.39s in Bulk

GOOD news from the Blackburn Group is contained in a statement issued on September 30. It reads:

"In amplification of the recent statement by the Minister of Supply, Mr. Aubrey Jones, that production of the NA.39 for the Admiralty was beginning, the Blackburn Group announce that a full production contract for a substantial quantity of NA.39 aircraft has now been placed on Blackburn Aircraft Ltd., with deliveries to be spread over the next few years.

"The Group also state that it is expected that orders will shortly be placed with Blackburn Engines for their new A.129 gas turbine for the Saunders-Roe P.531 helicopter, in which it is already flying. Saunders-Roe, in association with Westland, are confident that this helicopter will enter into large-scale production. The A.129 engine is about to be installed for the first time in the Westland Whirlwind helicopter.

René Caudron

WE record with regret that M. René Caudron, the pioneer French aircraft designer, died recently at Vron in north-east France at the age of 75. He and his elder brother Gaston, who was killed in a flying accident in 1915, started designing and building aeroplanes in 1908; and their products became famous before the First World War. In the United Kingdom these useful French

M. René Caudron (left) with the famous British pilot W. H. Ewen and a Caudron biplane (35 h.p. Anzani)—a "Flight" photograph of 1912

biplanes were built by the W. H. Ewen Aviation Co. Ltd. and were used at the Hendon flying-school. Caudrons were successfully flown in Australia, and in 1913 the Chinese Government ordered 12 of them. During the 1914-18 war, René Caudron designed and built both single- and twin-engined aircraft for the French Air Force. His two-seater G-3 biplane, for example, was said in contemporary accounts to possess "an excellent weight-lifting capacity" and "imperviousness to bad weather." He was also a successful constructor of seaplanes.

Caudron continued as an aircraft manufacturer and operator of a flying school until 1940. The company he started built mainly light aircraft, producing many successful high-speed machines in co-operation with the Renault Co. Shortly before the Second World War, Avions Caudron-Renault developed a light fighter, the Cyclone, powered by a 450 h.p. Renault engine.

Supersonic Survival

DURING a test flight over the Irish Sea on October 1 Mr. John Squier, English Electric chief production test pilot, was obliged to eject from a Lightning at supersonic speed and, after spending some 28 hr in his dinghy, came ashore unaided near Garliestown, Wigtown. The aircraft was a T.4 two-seater.

FROM ALL QUARTERS

The tracking-radar trace was lost at 11.25 a.m. when the T.4 was travelling northwards at supersonic speed at about 40,000ft. The nature of the emergency has yet to be revealed. The latest Martin-Baker Mk 4BS automatic seat was fitted; thus, when the pilot pulled the blind over his face, the canopy first blew off and then the seat left the aircraft at 80ft/sec. Immediately it left the aircraft the seat would have tilted into a horizontal, feet-first attitude stabilized by the first drogue. The pilot's legs would be firmly lashed and the seat pan would take most of the direct airloads. It has not been stated whether Mr. Squier was wearing partial-pressure clothing. The important factor in ejection is the indicated airspeed which, at a Mach number of 1.6 at between 30,000 and 40,000ft, would have been about 650 m.p.h. Investigations in America have shown that, just as the human body can withstand accelerations of up to 40g for extremely brief periods, it can also survive short pulses of very high blast.

All the automatic devices appear to have functioned and, on entering the water, Mr. Squier was able to inflate his lifejacket, get into his dinghy, fasten the protective apron and use the survival equipment. Though it seems probable that he was carrying a Sarah beacon, searching Shackletons or launches failed to sight the dinghy, although two launches, a merchant ship and an aircraft passed close by. He could discern the coast throughout the night. On the following day, after struggling for hours against wind and currents, he made the shore and found help.

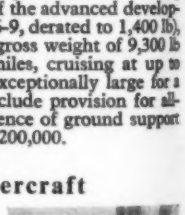
Although exhausted and suffering from shock and ear-ache, Mr. Squier was not seriously hurt and was expected to leave hospital at Stranraer last Tuesday. It says much for the numerous safety devices involved and for the presence of mind of the pilot that he should have come so well through his ordeal. The detailed investigation was begun earlier this week.

Cessna Utility Jet

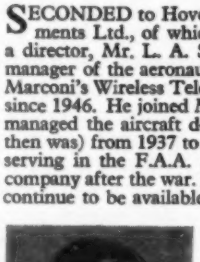
RECENTLY presented in mock-up form, the Cessna 407 has been privately evolved from the T-37 (standard U.S.A.F. trainer) to meet an alleged "pressing military need for a low-cost jet replacement for the training and utility aircraft now being phased out of service." Powered by two of the advanced developments of the Marboré (the Continental 356-9, derated to 1,400 lb), the 407 is a remarkable aircraft, having a gross weight of 9,300 lb and operational ranges up to 1,380 n. miles, cruising at up to 404 kt. The cabin (dP, 7.5 lb/sq in) is exceptionally large for a four-seater, and features of the aircraft include provision for all-weather operation and complete independence of ground support equipment. Selling price might be about $200,000.

Marconi Executive for Hovercraft

SECONDED to Hovercraft Developments Ltd., of which he is already a director, Mr. L. A. Sweny has been manager of the aeronautical division of Marconi's Wireless Telegraph Co. Ltd., since 1946. He joined Marconi in 1936, managed the aircraft department (as it then was) from 1937 to 1942, then after serving in the F.A.A. returned to the company after the war. His services will continue to be available to Marconi.



Mr. Sweny



Dr. O'Kane

Dr. B. J. O'Kane succeeds Mr. Sweny as manager of the aeronautical division. He joined the company in 1952 as chief air radio engineer. He was with G.E.C. from 1935 to 1941 and again after wartime secondment to the Telecommunications Research Establishment, Malvern. During the period 1947-52 he was chief engineer, International Aeradio Ltd.

***TREBLE VICTORY** for No. 617 Sqn. in the R.A.F. Bomber Command annual bombing and navigation competition is marked by this presentation of awards at R.A.F. Lindholme last Friday by the A.O.C-in-C. Bomber Command, Air Marshal Sir Kenneth Cross, when the squadron C.O., W/C. D. Bower, received the Laurence Minot, Armament Officers' and Sir Philip Sassoon Trophies won by his Vulcan crews*

IN BRIEF

First of the pre-production Saunders-Roe P.531 helicopters for the Royal Navy has been delivered.

Newly elected members of the board of the British-Swedish Chamber of Commerce in Stockholm include Mr. C. F. Uwins, deputy chairman of the Bristol Aeroplane Co. Ltd.

Sir Roy Dobson, managing director of A. V. Roe & Co. Ltd., has said that Vulcan B.2 and Avro 748 production would not be affected as a result of last weekend's fire at the company's Chadderton works. Damage was estimated at between £1m and £2m and the biggest problem was the loss of production records.

Bristol Siddeley Engines Ltd. are the latest British company to join Aircraft Exchange Inc.

Decca Navigator equipment enabled a Whirlwind helicopter of No. 22 Sqn., an R.A.F. air-sea rescue unit, to make a successful 70-mile flight from Brighton through early-morning fog to Stoke Mandeville (Bucks) spinal injuries centre recently, carrying a girl whose neck had been broken in a road accident.

THE ANGLO-AMERICAN CONFERENCE

DURING last weekend approximately 65 members of the Royal Aeronautical Society flew to New York City to take part in the Seventh Anglo-American Conference. Scheduled to encompass 13 days of meetings and field trips, this year's conference—the first took place in 1947—is notable for the fact that the Canadian Aeronautical Institute has for the first time been formally invited to co-sponsor the event, together with the R.Ae.S. and the Institute of the Aeronautical Sciences. Mr. Peter Masefield, president of the R.Ae.S., took note of this historical departure in his opening message to the assembled delegates and expressed particular pleasure at the presence of the Canadian members. Similar comments were voiced by Mr. William Littlewood, president of the I.A.S.

A further, more formal, note of greeting was sent to the Assembly delegates by command of the Queen. On behalf of Her Majesty, Sir Michael Adeane, private secretary, addressed this letter to Mr. Masefield: "The Queen, as patron of the Royal Aeronautical Society, sends her best wishes for the success of your deliberations. We all look forward to a conference which will at once be stimulating in its technical aspects and heart-warming in the renewal of old and for the formation of new friendships."

And, indeed, many such old friendships were renewed, and others made, during the registration period on Sunday afternoon (October 4) at the Astor Hotel, and during the hour preceding the opening session the following morning. Following the opening formalities, R. J. Atkinson (head of Structural Fatigue Division, Structures Department, the Royal Aircraft Establishment) presented his paper entitled *Aircraft Fatigue—A Survey of Current Thought*. In his introductory remarks Mr. Atkinson pointed out that structural fatigue had been a major consideration in the design and operation of aircraft since post-war days, and had required unprecedented expenditure of research and development effort. The first oojective, safety, had now been largely achieved. This had been accomplished in the main by an awareness on the part of design teams that structural fatigue was a vital consideration. Universal acceptance of the need for "rigorous and systematic" design procedures followed, and today's aircraft are quite safe from a fatigue standpoint. However, a second aspect—that of efficiency of structural design (to withstand fatigue)—was also of concern to the aircraft designer.

The lecturer next spoke of fail-safe and safe-life design philosophies. The former technique referred to designs in which a small measure of cracking was permitted, while the latter implied a design in which no cracking was allowed. The two were distinguished by the degree to which reliance could be placed in inspection to ensure safety. Generally, both philosophies were incorporated in a given structure; designers traditionally sought designs having long crack-free lives and aimed, as far as practicable, to design structures so that cracks could be easily detected before they reached dangerous proportions.

Reliance on inspection to discover cracks, and to assure quick structural reinforcements where necessary, presented certain problems. Whereas the larger airlines maintained a high standard of inspection, airlines in out-of-the-way places perhaps lacked adequate inspection and repair facilities. As a result, suggested Mr. Atkinson, the design of a structure need be suited to the market.

In reference to gust loads, the lecturer said turbulence was responsible for most of the fatigue action in flight of transport aircraft, and might even be more significant than manœuvres for low-flying high-speed military aircraft. Interesting data collected on both sides of the Atlantic had shown that below 5,000ft the turbulence over land was at least twice as severe as that over the sea. With regard to normal accelerations on military aircraft, the use of a fatigue-load meter was almost obligatory if safety was to be preserved with economy.

Summarizing, the lecturer stated: "It appears that the designer can make a good first shot with the knowledge now available. Nevertheless, confidence in design ability is not yet sufficient to forego the final check of some form of test, since basically a small error in a highly localized stress results in a big change in endurance." Comprehensive tests on complete structures were the best way of proving structural integrity. Fatigue tests following static strength tests were misleading; "the life on test may be longer than it should be and the failures in the wrong place." Hence, when only one specimen was available, fatigue tests must be completed before static strength tests. Fatigue-testing costs of an aircraft were comparable to the cost of a fully equipped aircraft.

Following a luncheon break, E. C. Cornford, D. G. King-Hele and R. H. Merson of the Guided Weapons Department of the R.A.E. discussed *Recent Studies of Satellite Orbits*. Their paper showed that the perturbations to Earth-satellite orbits caused by atmosphere and by Earth oblateness were of quite different natures. Atmospheric drag reduced eccentricity and the length of the major axis (and consequently the period of revolution) of a satellite. The rate of changes of these parameters depended upon air density at perigee, and the rates of change gradually increased as perigee altitude decreased. Earth oblateness, on the other hand, caused rotation of the plane of the orbit (about the Earth's axis) and rotation of the major axis (in the orbital plane) but did not appreciably change eccentricity. Minor perturbations were caused by the gravitational attractions of the sun and moon.

The results of 1,000 separate observations of Sputnik 2 and the spent rocket casing of Sputnik 3 had been analyzed, and the curves showed some interesting phenomena. When comparing "air density" with "average air density" over a long period of time, there was a general impression of irregularity. The value of air density on any particular day was a poor guide to the value on some other day. For example, under similar conditions of altitude, etc., the density of air taken on October 17 last year was 25 per cent greater than that on October 14. Maximum and minimum values of density showed a strong tendency to recur at 28-day intervals. The movement of the perigee from daylight to darkness, and variations of density with latitude, could be ruled out as possible cause of the noted periodicity. "Lunar tides" were similarly held to be of no consequence in creating the 28-day cycle. Most likely, the periodic change in density (at perigee) was caused by solar disturbances. It appeared probable that the air density at heights of between 100 and 350 n.m. (and over a wide range of latitudes) was strongly influenced by charged particles emanating from the Sun on a regular 27/28-day basis.

Also presented last Monday afternoon was a paper by R. D. Hiscocks of de Havilland Aircraft of Canada, Ltd., *The Caribou Utility STOL Aircraft*. Noting the differences between the requirements of the military and needs of the civilian aircraft operator, Mr. Hiscocks stated that it was often the rôle of the aeroplane designer to strive to strike a happy compromise between the two in the interests of economy. Such compromises had been effected in the case of the Beaver and Otter, both of which were widely used in military and civilian applications. Experience with these aircraft had provided much useful background.

The preliminary studies which culminated in the production of the Caribou began some years ago with a paper design for a Twin Otter. Grossing 13,000 lb and possessing twin Otter-type powerplants and fixed landing gear, this initial study was rejected early for the very simple reason that the aircraft could not carry a payload appreciably larger than that of the basic Otter. Many other variants were discarded before the final configuration was frozen. The ultimate arrangement of the aeroplane was dictated by performance requirements, e.g., STOL characteristics, a good climb after take-off, and a reasonable single engine ceiling on a hot day with an economical powerplant. Direct operating costs were, as a result of these demands, somewhat higher than those of large fixed-wing aircraft, but very much lower than those of helicopters.

Speaking of the reasons behind the change from a twin tail to a single vertical tail, Mr. Hiscocks said that the twin unit brought with it structural disadvantages which added weight to the rear fuselage. In addition, the difficulties of providing adequate aerodynamic balance for the elevators had been under-estimated. The lecturer showed figures comparing the performance of the existing aeroplane with a variant powered by twin turboprops of "projected 1,920 e.s.h.p." The turboprop version, he said, offered gains only for very short ranges; however, the picture would change when improved s.f.c.s were available in small turboprops.

Three prototype Caribous had been in continuous use in the flight-development programme. Measured performance compared favourably with preliminary estimates. Strangely, flutter had been encountered in early production models but not in the prototypes. It was finally established that the flutter was incurred when the fuselage was lengthened in progressing from prototype to production models. The impedance characteristics of the elevator control system were sufficiently sensitive to fuselage deflection to create the flutter. Appropriate corrective measures, however, had eliminated this problem.

Harry Pearson, chief research engineer, Rolls-Royce Ltd., concluded the first afternoon's session with his paper, *Engines for VTOL Aircraft*.

(*Continued on page 356*)

Footnote: *These summaries concern only the British delegates' lectures; some U.S. papers will be dealt with in a subsequent issue.*

Missiles and Spaceflight

AUSTRALIAN SPACE PLANS

Following a visit last month to the Weapons Research Establishment at Woomera, Dr. D. F. Martyn, chairman of the Australian National Committee on Space Research, said that a specific programme for Australian space research was being submitted to the Federal Government. The space committee's chief concern would be instrumentation, both optical and electronic, rather than rocketry.

It is believed that the Australian programme will involve the use of the indigenous Long Tom vehicle or a modified version of this rocket.

ORBITAL ALBM FAILURE

For the second time the U.S. Air Force have failed in an attempt to launch a ballistic missile from a bomber and place it close to the orbit of a satellite. The first occasion, involving a missile transferred from a B-47 to the orbit of Explorer 6, occurred on September 25 and the project was finally abandoned. The second attempt involved an ALBM which was to have been launched by a B-58 operating from Eglin A.F.B., Fla, over the Gulf Coast test range. It was intended that the missile would be placed in the north/south orbit of Discoverer 5; apparently the missile left the B-58 but failed to transmit any information, and the Air Force later stated that "test objectives were not accomplished." It was intended that the test would provide data "concerning the trajectory of an ALBM in the vicinity of Discoverer 5" with a view to the ultimate improvement of guidance systems.

ZUNI

On September 28 the U.S. Navy revealed details of Zuni, much the largest of the current crop of American spin-stabilized rockets. Intended for air-to-air or air-to-ground use, Zuni has a length of 9ft, a diameter of 5in and weighs 110 lb at firing. It is driven by a solid charge, has four folding fins and is fired singly or in salvo (the F4D Skyray in the background to the official photograph shows rounds being loaded into a four-tube launcher). Although its price is no more than £140, it is claimed to be able to carry warheads "second only to a nuclear charge in destructive effect," ranging from fragmentation to armour-piercing.

SPACEFLIGHT TYRE

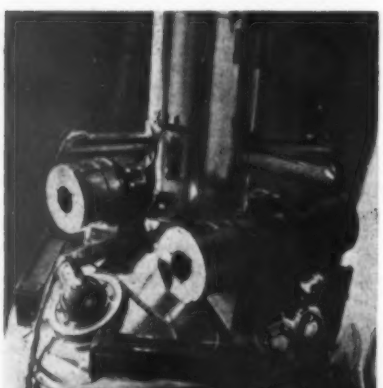
"No rubber, no fabric and no inflation" are the features of a tyre produced by Goodyear Tire and Rubber Co., of Akron, Ohio, "for application in spaceflight." More specifically, it is intended for use as a landing wheel for vehicles which re-enter through gaseous atmospheres.

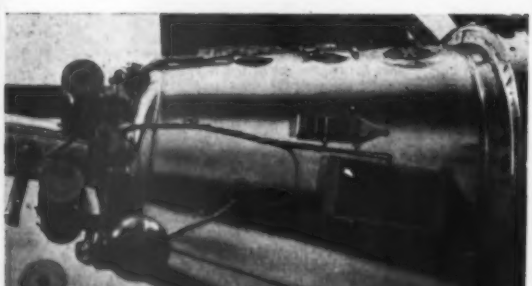
The tyre is essentially fabricated from wire, and according to the material employed can withstand temperatures from 1,000 to 2,000 deg F. Notwithstanding its unique construction the tyre is said have load deflection characteristics similar to those of pneumatic tyres. It also has a higher rolling resistance, and is naturally proof against blow-outs. Additional advantages suggested are higher ability to absorb runway irregularities and landing impacts, greater total contact area and, when used in

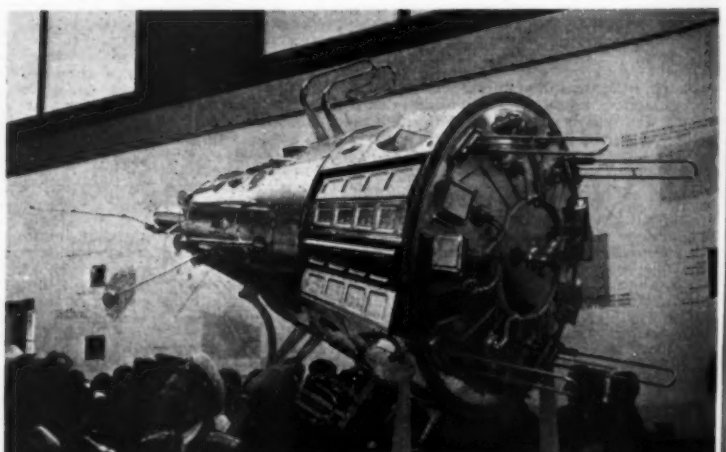
[Contd. on page 349

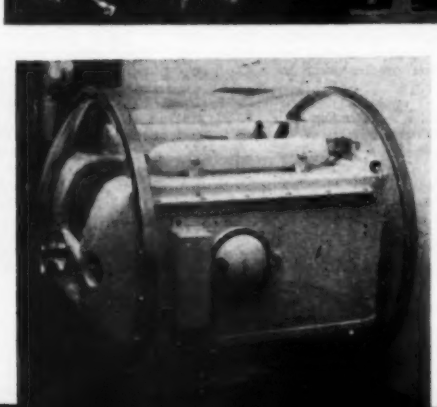
SOVIET HEAVYWEIGHT HARDWEAR

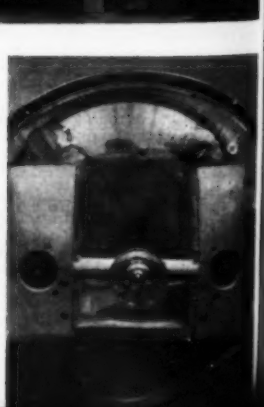
Russia's 2,925 lb Sputnik 3, launched in May 1958, is still the heaviest artificial Earth satellite. Pictures taken at the recent Agricultural and Industrial Exhibition in Moscow











Immediately below is the Sputnik 3 replica shown at the exhibition. Protruding from nose, sides and base are three types of radio aerial, and below the nose is an ionic density aerial. Near the base are large adjustable flaps, eight pairs of which were used to vary the sputnik's coefficient of radiation. Micrometeorite recorders are visible between the base aerials.

Sputnik 3 details (left, top to bottom) show (1) two cosmic-ray counters (photomultipliers) straddling central nose magnetometer tube above small solar-cell plates; (2) two rectangular micrometeor recording plates and (in upper central and right hand circular apertures) manometer tube and electrostatic fluxmeter gate; and (3) recessed mass-spectrometer tube (near upper micrometeorite recorders), electrostatic fluxmeter with two magnetic manometers, and lower micrometeorite recorder. Replica of dog Laika's compartment in Sputnik 2 (bottom centre and right) was fur-lined, and incorporated two air-circulation fans. Central cup on compartment floor had food capsule tipped into it periodically.

Of particular interest in a page on which we record the launching of the Soviet "automatic interplanetary station" on the second anniversary of the firing into orbit of Sputnik 1, this working model of a future "cosmic station" was displayed in the Electrification Pavilion at the U.S.S.R. National Economy Achievements Exhibition earlier this year

Missiles and Spaceflight . . .

conjunction with a skid, better scavenging action, greater cooling of the skid surface and improved directional stability. Exhaustive testing has been conducted on Goodyear's dynamometer, and further tests are scheduled at the NASA Langley Laboratory.

AROUND THE MOON?

A lunar probe intended to circle the Moon and obtain photographs of its distant side was launched by the Soviet Union on October 4, the second anniversary of the firing into orbit of Sputnik 1, the first artificial Earth satellite. Confidence that the probe would be successful was implied in the advance notice of its planned objective, an unusual feature in initial Russian announcements of space achievements.

The probe was described as an "automatic interplanetary station" weighing 614 lb, and was reported to have been precisely on course at a distance from the Earth of 145,000 km (about 90,000 miles) at 3 p.m. G.M.T. on October 4. According to Tass it would pass at a distance of 10,000 km (about 6,250 miles) from the Moon, circle it, and return "to the region of the Earth." (According to a later Tass estimate, the station was expected to reach a closest point of 4,350 miles from the Moon at 2 p.m. G.M.T. on Tuesday, October 6.)

A multi-stage rocket was used to launch the probe, which carried two solar-powered transmitters. These functioned for 2-4 hours per day on radio command from a "co-ordinating and computing centre" on Earth. From this centre, it was further stated, the trajectory of the probe could be controlled as it circled the Moon and returned towards the Earth. The first two-hour transmission of data had confirmed the normal functioning of all the instruments carried.

The final stage of the launching rocket was said to weigh 1,553 kg (3,424 lb) and to have contained "measuring equipment with power sources" weighing 156.5 kg (345 lb). The station itself carried an automatic temperature control system as well as the scientific and radio equipment.

The Tass science correspondent said that it could be reasonably supposed that the photographs to be taken of the hitherto unseen side of the Moon "will be successfully transmitted by automatic radio apparatus when the station returns towards the Earth."

"A broad programme of scientific inquiry" would be carried out by the probe. As well as providing information about the far side of the Moon, the station could telemeter back data concerning the lunar atmosphere and pave the way to overcoming flight problems such as directional control near the Moon's surface, leading finally to manned spaceflight around the Moon.

Following receipt of a telegram from Moscow giving an estimated position of the probe, the radio telescope at Manchester University's Jodrell Bank experimental station picked up radio signals from it on 183.6 Mc/s for a period of about 20 minutes on October 4, and again (on 39.896 Mc/s also) on subsequent days.

SPACE STRATEGY

Study contracts to examine the feasibility of "strategic interplanetary systems" are being handled by a number of U.S. companies for Air Research and Development Command of the U.S.A.F. The Allison division of General Motors, Westinghouse Electric, and Douglas Aircraft are working on Study Requirement 182 for a strategic interplanetary system; Aerojet-General, Douglas Aircraft and North American Aviation are analysing the use of the Moon as a strategic military base (SR-192); and a third project, SR-183, concerns the establishment of a lunar observatory.

A Little Joe rocket and a cast-iron model of a Project Mercury capsule were successfully tested at Wallops Island, Virginia, on October 4. Rocket and capsule were deliberately destroyed 2½ min after launching, after an altitude of about 40 miles had been attained. Purpose of the firing was to test the launching, propulsion and destruction systems.

During a visit to the United Kingdom to see British surface-to-air guided weapons systems, a Swiss military guided weapons mission, headed by Brig. R. V. Wattenwyl, spent four days studying the resources of the English Electric Aviation Company's Guided Weapons Division. They visited Stevenage, Aberporth (where a successful Thunderbird firing was witnessed) and Manorbier.

The U.S. National Aeronautics and Space Administration announced on October 2 that it will negotiate with Lockheed Aircraft Corp., Georgia Division, on a contract to provide basic engineering data in a "continuing feasibility investigation" of a nuclear rocket system. Work is expected to take more than three years and cost over one million dollars, and the main part will be carried out at NASA's Plum Brook reactor facility near Sandusky, Ohio.

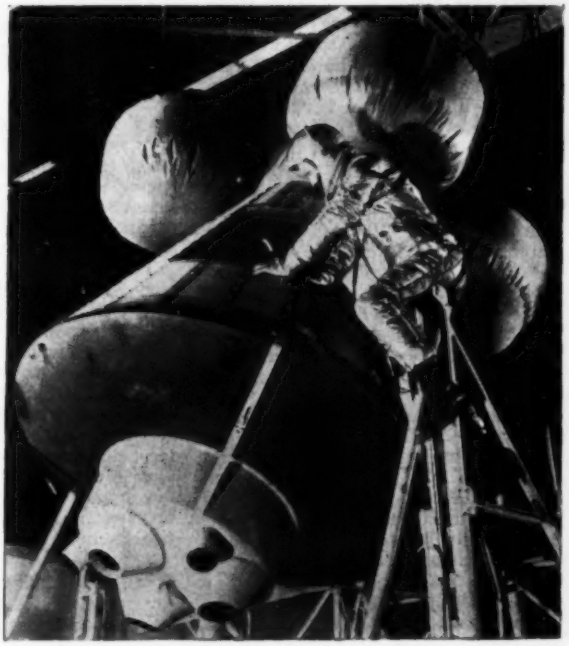
Much attention is currently being focussed on the development of fuel cells which, by combining hydrogen and oxygen, can turn the energy of their combustion directly into electrical power. Mention has already been made of the British Bacon cell (*Flight*, September 4); Pratt and Whitney Aircraft have now announced that, in association with the Patterson-Moos Division of the Universal Winding Co., they are engaged in the development of a device known as the Hydrox fuel cell. Patterson-Moos are concentrating on fuel-cell technology while Pratt and Whitney work on the development of systems and system components (for satellites and other spacecraft, for example).

On September 28, the most ambitious test firing so far scheduled for the Polaris fleet ballistic missile ended in failure "several miles off Cape Canaveral." The round comprised a complete airframe, first- and second-stage propulsion systems and a simulated warhead, which it was intended would be placed on a specified target at a range of 900 miles. This distance appears to be the design range of the current first-generation Polaris, although it has been suggested that 1,200 miles is hoped for as a result of the use of propellants of higher specific impulse, coupled with an airframe fabricated from even more advanced steel with an improved tensile strength.

Brief data are now available for Nord-Aviation's new surface-to-air missile designated A.C.A.M. 5301. Having an appearance resembling a scaled-up Type 5103 air-to-air missile, the 5301 has the following characteristics: propulsion by two-stage solid charge; control by jet-deflection of the cruising charge; firing weight, 1,058 lb; body diameter, 13.45in; length overall, 14ft 9.2in; span of wing cruciform, 59in; warhead weight, 88.2 lb; guidance by radio command during 24 sec propulsion period; flight speed, over 1,342 m.p.h.; range, approximately 9.5 miles.

An announcement from British Oxygen Aviation Services (member of the British Oxygen Group) stated on September 23 that a total-loss evaporative cooling system has been evolved for missiles and supersonic aircraft. In such systems a liquefied gas—such as nitrogen—is expanded from a heat exchanger and eventually to atmosphere, the flow being governed to produce the required degree of cooling of the equipment concerned.

Mock-up of Project Mercury manned satellite capsule at McDonnell Aircraft Corp., St. Louis. Note retro-rockets and flotation bags



Straight and Level

JUST two years ago (on October 4, to be exact) the launching of Sputnik 1 released mankind from the ties which have always bound him to the Earth. The second anniversary of that event saw a rocket launched to the far side of the Moon. The first two years of the Space Age can now be seen in sufficient perspective for me to attempt to offer some words of extraordinary wisdom.

In general the picture appears to me to be like this. Russia has achieved all the important "firsts"; the first man-made device to orbit the Earth, the first to orbit the Sun, the first to impact on the Moon and the first to carry an instrumented, live, mammal—Laika—into the darkness beyond our atmosphere. The Americans have thrown small but well-instrumented packages into orbit around the Earth and Sun, and has probably gathered in more scientific data; but in spite of their massive technological strength they have achieved no notable "first" and seem to have devoted much of their time to explaining away their own spectacular failures and inventing Russian ones. (Doubtless the Russians have had at least as many failures as the Americans, but they have an uninquisitive Press.)

* * *

One factor stands out which certain engineers predicted as early as 1955: spaceflight costs money; ballistic missiles cost more money; ballistic missiles have to be exceedingly reliable; so do space vehicles. So the obvious thing to do is to use a ballistic missile as the basis for a space vehicle. This seems so self-evident that I still cannot quite think what the U.S. Navy (among others) were thinking of when they sponsored the Vanguard. Moreover, how is it that almost all the spade-work involved in throwing up American hardware has been done by the Jupiter C (a modified Redstone), the Jupiter and the Thor? The only Atlas with space aspirations was designed to do nothing but transmit a peace-loving message from President Eisenhower. Who can explain the fact that, had NASA used the Atlas from the start, all the "firsts" later than Sputnik I would probably be American?

We British can at least learn by others' mistakes. I certainly hope we will wring the last drop of space information out of Blue Streak before we do anything else.

● "I don't think one should differentiate between the Commonwealth and the rest of the world. I think we still tend to look on the Commonwealth as an annexe of Britain and take it for granted that if we make an aeroplane the Commonwealth will automatically buy it—"

"That has not happened in Australia in the last two years—"

"It certainly has not happened, and I think one reason why it has not happened is just because we do not treat the Commonwealth from a business point of view as a foreign country that needs selling just as hard as any other country."

—From a B.B.C. Home Service programme, "Matters of the Moment." The speakers were Mr. J. D. Pearson of Rolls-Royce and (interjecting) Sir Arthur Vere Harvey.

Who is this chap, and what does he think he's doing? Is he Cæsar, bestriding the narrow world like a colossus? Or Faust, in the act of being damned? Or Dumbo Willans, going out feet first? The picture-agency caption claims that he is a flight-deck crewman standing in the wake of smoke left by the steam catapult of H.M.S. *Victorious*

● "*The argument for applying low fares to a particular technical principle, i.e., a turboprop as against a turbojet engine, seems very dubious indeed and smacks more than a little of Luddism.*" —Mr. Frank Beswick, writing in *Flight* last week.

The 19th century Luddites, led by one Ned Ludd of Sherwood Forest, went about, often by night and in disguise, smashing up industrial machinery. They were senselessly trying to stop technical progress in order to protect their jobs.

so the Fare Differentialists. They are trying to *encourage* technical progress in a field so far sadly neglected—the field of minimum operating cost.

The airlines refuse to ask for the lowest aircraft operating cost that technology can provide. Is it not this which smacks more than a little of Luddism?

● A sensational new breakthrough in the economics of turbofan jet engines has been claimed by British air expert Dr. J. Nit. In a paper published in this month's issue of *Air Fare*, he describes a modification to the principle of the turbofan jet engine which, if adopted, "will slash air fares by a half."

Dr. Nit proposes to use a front-mounted single-stage fan, with four variable-pitch blades of wide chord. This would be coupled to the compressor *via* a reduction gear. All the surplus energy in the jet—at present wasted—would be put into this fan, which for maximum propulsive efficiency would be of large diameter—"so large that the heavy, drag-producing outer duct of present turbofans can be thrown away."

The result would be "a slightly lower aircraft speed, but absolutely maximized propulsive efficiency and hence economy."

Asked by one of my reporters whether his invention was nothing more than a turboprop, Dr. Nit replied rather testily: "Rubbish. I have worked from basic principles, and any similarity is purely coincidental."

● What looks like a straightforward formation picture on the Service Aviation page this week—a Turbulent and three Hunters—was in fact an extremely sharp *coup d'oeil* by Air Ministry chief photographer "Mick" Chase and the pilots concerned.

As the Turbulent was doing about 85 m.p.h. flat out after a dive, and the Hunters closing in at about 140 with flaps down, Chase (in a Hunter T.7) had to press his shutter at exactly the right micro-second. The result is a charmingly theatrical piece of deception.

● It was in Philadelphia, wasn't it, where they sounded the Liberty Bell, and where, I believe, the old bell still hangs (like Drake's drum) ready to rally the nation. And in Philadelphia today the spirit of Drake endures, quite literally, as well as the spirit of Independence; in witness whereof I quote verbatim a Reuter message: "The *Philadelphia Inquirer* said today it was 'a shame that the British now feel it is no longer feasible to keep a Spitfire in flying condition.' Commenting on the crash of the last serviceable Spitfire during the Battle of Britain flypast, it said, 'It is as if the last of Sir Francis Drake's fleet were headed for the scrap heap.' It said that 'we owe our freedom' to the Spitfire's speed, manoeuvrability, and guns, and added, 'If there is no other recourse but to ground the heroic old warrior, its retirement should be honoured by permanent preservation in fitting surroundings both in Britain and the United States.'"

To the editor of a great American newspaper go my warm congratulations—and the assurance that we still have Spitfires in Britain and that one or more will fly again.

ROGER BACON

This elegant touring conversion of the D.H. Chipmunk was recently completed for Airways Aero Club by Bristol Aircraft, whose managing director, Mr. Peter Masefield, is piloting the machine in this picture

Sport and Business

THE TIGER CLUB'S NEW BASE following the closure of Croydon Airport on September 30 (reported on page 354) is Redhill, the private aerodrome owned and operated by British Air Transport Ltd. New fuelling facilities are being installed at Redhill and maintenance of the Tiger Club aircraft there will be by Rollason Aircraft and Engines personnel.

The Rollason company's Croydon factory is continuing to operate, but additional accommodation has been acquired at Biggin Hill and it is from here that all the company's flying will be carried out. Repair, maintenance and C. of A. work on light aircraft can be handled by Rollasons at Biggin Hill, and both short-term and long-term hangarage is available.

AT BIGGIN HILL, which, according to Surrey and Kent Flying Club, has now "proved its worth as a club-type aerodrome," the operation of the airfield is to be the responsibility of Surrey Aviation Ltd. A new company, Surrey and Kent Flying Club Ltd., will govern the affairs of this club, which moved from Croydon together with a number of smaller clubs and groups in February this year. The second major club now flying at Biggin Hill is the Airways Aero organization, which left Croydon in July.

Ambitious plans for the development of Biggin Hill as a "private pilots' Mecca" were announced last weekend by Edward Drewery and Jock Maitland of Surrey Aviation Ltd. As a first step a new control tower is to be built, and it is hoped later to lease the main 2,000 yd runway.

OPERATING A TAYLORCRAFT PLUS D at a flying rate of £2 12s per hour, the Alouette Flying Club has been formed at Biggin Hill. *Ab initio* members can be accepted, and the secretary of the club is W. A. Nolan, 6 Starfield Road, London, W.12.

A NEW U.S. LIGHT AIRCRAFT, the Meyers 200, was used by Peter Gluckmann last month in a solo round-the-world flight beginning and ending at San Francisco. The 22,800-mile-plus journey, which Gluckmann hoped to complete within two weeks, took 29 days 6 hr 8 min 52.2 sec (according to the F.A.I.) and ended on September 21.

Produced by Meyers Aircraft Co. of Tecumsah, Michigan, the 200 is an all-metal four-seater powered by a 240 h.p. Continental O-470M engine. At a gross weight of 3,000 lb the aircraft cruises at 180 m.p.h. on 55 per cent power at 10,000ft; maximum speed at sea level is 208 m.p.h. Normal fuel tankage amounts to 40 U.S. gal and gives a 700-mile range at 180 m.p.h., while auxiliary tanks of 34 gal increase this to 1,300 miles. Span is 30ft 6in and length 24ft 5in.

A PARACHUTING CONTEST between members of the seven parachute clubs in Britain was won at Sandown on September 27 by Cpl. Norman Hoffman (left) of the R.A.F. Cpl. Hoffman's club, the British Skydivers, came first in the team event. The Sandown competition followed the cancellation of the planned national parachute championships which were to have been held during the National Air Race meeting at Coventry, but were cancelled due to bad weather. R.Ae.C. observers were not present at Sandown.

CATERING AND ACCOMMODATION is now provided at Denham Aerodrome by the Hawksridge Restaurant, recently opened by two Denham Flying Club members, Joan and Denis Bootle. The club's Link trainer should be in operation later this month under Grahame Campion, and a winter programme of parties, film shows and visits is being organized by the pilots' committee. Visitors to Denham are reminded that a variable circuit is in force at present.

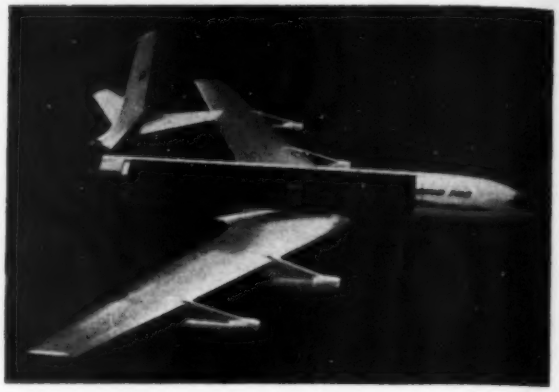
RETROSPECT

From "Flight" of October 9, 1909

Learning to Fly in Three Minutes: On the 30th ult., a striking demonstration of the wonderfully quick way in which some men can grasp the essential principles of a flying machine was witnessed at Issy. In response to a note to the effect that the flyer was ready, M. Guy Blanck repaired to the famous military ground to take his first lesson. After a three-minute explanation from M. Collin, the Bleriot instructor, M. Blanck got into the driver's seat, had the motor started, and flew across the ground in a straight line. In a second flight he made several turnings. The next day he had just started when a derangement of the motor made it necessary to take a few days' rest.

Reported on this page is the recent round-the-world flight in a Meyers 200 by Peter Gluckmann. Seen below on arrival at San Francisco, Mr. Gluckmann holds his mechanical-bird-in-gilded-cage mascot

AIR COMMERCE



Payload of the swing-tail Boeing 735 freighter (dimensions as 707-320 with a one foot longer fuselage) is 98,217 lb on a gross weight of 316,000 lb, and 64,000 lb over a range of 3,500 n.m. Powerplants are Pratt and Whitney JT3D-3W turbofans of 18,000 lb thrust

B.O.A.C. COMET 4 ANNIVERSARY

IN the twelve months since B.O.A.C. introduced de Havilland Comet 4s into service on October 4, 1958, three-quarters of all westbound North Atlantic flights (73 per cent to be exact) have arrived within 15 minutes of the advertised time. Arrivals within an hour of schedule were 89 per cent, and respective regularities eastbound were 27 and 77 per cent. There was only one Avon engine shutdown in flight on the North Atlantic route; this was caused by a faulty fuel-control unit.

These facts were given by Mr. Basil Smallpeice, managing director of B.O.A.C., on the eve of the first anniversary of the Corporation's Comet 4 operations. The westbound North Atlantic regularity record was, he said, a "remarkable performance, substantially better than that achieved by any other type of aircraft B.O.A.C. has ever had in service on these routes." Other statistics for Comet 4 operations on all routes, including eastern routes, were as follows: Passengers carried, 76,000; seat-miles flown, 364,284,000; passenger-miles flown, 269,770,000; passenger load-factor, 74 per cent; revenue flying hours, 15,150.

The Comet 4, say B.O.A.C., was largely responsible for the fact that in the period April 1 to September 19, B.O.A.C.'s North Atlantic passenger traffic was up 40 per cent on the corresponding summer period in 1958.

Mr. Smallpeice noted that, in the same period, B.O.A.C.'s eastern-routes traffic increased by 22 per cent, though business on the southern routes went up by only 2 per cent.

As from next April, Comet 4s will be displaced from the Atlantic routes by Boeing 707-420s, the first of which is due to be delivered in December. The programme for new Comet 4 services is as follows: November 1, Australia; December 1, South Africa; January 25, South America.

The chairman of B.O.A.C., Sir Gerard d'Erlanger, indicated last week that the Corporation expect to inaugurate a Polar route service between London and San Francisco (rights for which have been held for many years but—owing to shortage of capacity—never taken up) in the autumn of 1960. Boeing 707-420s will be used at a frequency of twice weekly initially, rising to thrice weekly shortly afterwards.

BRANIFF ELECTRA ACCIDENT

ALL 28 passengers and six crew on board a Lockheed Electra of Braniff International Airways on September 29 lost their lives when the aircraft crashed 68 miles south-east of Waco, near Dallas, on the nightly tourist flight from Houston to New York via Dallas and Washington.

According to a statement by an F.A.A. official at Waco airfield, the Electra was flying at about 15,000ft on an IFR flight plan. It made its last report at 2305 hr, and crashed (according to the same source) at about 2313 hr. Scheduled departure time from Houston appears on the timetable as 2215 hr. Waco is about 190 miles from Houston, and about 100 miles from Dallas. The weather at the time of the crash is said to have been good.

An eye-witness said that she and her husband saw the aircraft "explode in the air as it came over our house way up in the sky. It kept going on and it looked like a falling star. The light went out and we heard a terrific noise like a jet breaking the sound barrier, then we heard it hit the ground and saw a tremendous explosion."

Wreckage was scattered over a square mile of wooded farm land, the largest piece being a section of fuselage about 15 or 20ft long. Only one engine, according to AP, was found in the crash area. The crew were as follows: Capt. W. E. Stone (47), captain; co-pilot Don Hollowell; flight engineer Roland Longhill, and three stewardesses. A full C.A.B. inquiry was opened immediately.

ACCIDENTS IN STATISTICS

ONE of the conclusions of the M.T.C.A.'s ninth survey* of accidents to British-registered aircraft is that the record in 1957 fell short of that of the year before. There were 120 accidents to aircraft and gliders in 1957 compared with 88 in 1955 and 96 in 1956; and of concern is the increase in accidents per passenger-mile. Taking the most commonly used yardstick, the passenger fatality rate per 100 million passenger-miles, the figure was 0.7 in 1955 and 1.4 in 1956. In 1957 it was 2.3, ten times more than the corresponding rate for U.S. domestic and international domestic carriers in 1957 of 0.22.

The trend is better shown by comparing four-year periods. Between 1952 and 1956 the rate per 100 million passenger-miles with U.K.-registered aircraft was 2.3, while between 1953 and 1957 it rose to 2.6—a figure which reflects the poor safety record of 1953, when the rate per 100 million passenger-miles rose to 4.3.

There were 11 accidents to public transport aircraft during the year under review (compared with 15 the year before), but only four of these occurred on scheduled public services. Seven were attributed to crew error, one to fatigue and one to powerplant failure. The causes for the remaining two have not been established. The survey lists every accident by cause and gives a summary of what occurred, but aircraft, places and dates are not included.

*"*A Survey of Accidents to Aircraft of the United Kingdom in the year ended December 31, 1957." H.M. Stationery Office, price 2s 6d.*

MARKET MARK-DOWN

THE American used-airliner dealers F. B. Ayer have reduced the price of 16 of the 30 ex-A.A. Convair 240s the company contracted to buy a year ago from $250,000 to $200,000. Of the 80 used airliners purchased by F. B. Ayer to date (30 A.A. Convairs, 45 A.A. DC-6-series, three Continental Convair 440s and two DC-6Bs) 23 have been handed over to the dealer. Of these 13 240s, three 440s and two DC-6Bs have been sold or leased.

Other used-aircraft news is that Aircraft Exchange have decided to publish their Market Report fortnightly instead of weekly because "the current aircraft market is not sufficiently active."

BRISTOL BRÉGUET FOR SILVER CITY?

WITHIN the 90 shopping days to Christmas, Silver City is to order for itself a present for which it has waited four years—new aircraft for the Channel Air Ferry. Announcing new fares for the winter season in London last week—they are the lowest that Silver City has ever offered—Mr. Eoin Mekie, the airline's chairman, said that within three months he would make known the airline's choice of aircraft. It would be completely new and would be a joint Franco-British venture built to a Silver City specification; he hoped that it would find ready acceptance in passenger and freight service throughout the world.

The French and British partners (it was reported by the *Daily Express* the following day) are to be Bristol Aircraft and Bréguet, and the new aircraft is to be powered by two Rolls-Royce Darts and will accommodate up to six cars. Cruising speed, said the newspaper report, was expected to be below 300 m.p.h., and operating costs in a passenger-only version with uprated Dart engines under one penny per passenger-mile.

Bristol last week would neither confirm nor deny the existence of such a design and said that any announcement was premature; and Bréguet told *Flight* that the report was "inexact" and that no such inter-company agreement existed at the moment.

Undoubtedly there are good reasons for Silver City placing an order for a combined effort from the French and British aircraft industries. In Silver City service at least, the aircraft would be used exclusively between France and England, and it might be that in bargaining for new traffic rights in France the support of the French industry could be a worthwhile asset.

In announcing new winter fares, Mr. Mekie said that financial results of the year's operations—"although by no means all I had hoped for"—had been better than in the financial year ending on September 30, 1958; 67,435 cars had been carried compared with 50,006 the year before. Fares for the winter of 1959-60 have been reduced by an average of 13 per cent on the Le Touquet service, 30 per cent on the service to Calais and 33⅓ per cent to Ostend. For most makes of car Silver City claim that the air ferry is now the cheapest way of crossing the Channel. Services during the winter are to be increased over last year and cars will be ferried to Cherbourg on a year-round basis for the first time. There is also to be a new ferry and freight service between Hurn and Jersey and Jersey and Cherbourg.

AIR COMMERCE . . .

The Caravelle Today and Tomorrow

UNDER rather trying conditions at B.O.A.C.'s London Airport headquarters on September 30, M. Péan, chief engineer of Air France, gave the first lecture in the current session to the L.A.P. Branch of the Royal Aeronautical Society. His theme was *The Caravelle in Service*, and he struggled to make himself understood against a background of air conditioning noise, a misplaced microphone and a difficult language. Among the points made by the lecturer were references to developed Caravelles and a disclosure that the aircraft is to be equipped with a braking parachute.

It was his intention, said M. Péan, to talk about the Caravelle under the headings of early decisions, manufacture, test, orders, production and service; but the best comment that an airline could make was about the difficulties that they had experienced, and he would not neglect to mention those.

Decisions on the configuration of the aircraft had been made over several years. In 1951 the number of passengers, the range and the runway length were decided and decisions about jets and turboprops were discussed throughout 1952. Air France's decision to buy a medium-range jet was finally confirmed in 1954 and 1955. Engines of the right size—about 10,000 lb thrust—were then available and a twin jet was chosen because of its attractive economy and reduced maintenance.

M. Péan then went on to talk of the satisfactory progress of flight tests, of structural changes that were incorporated when the first production aeroplane was produced, and of the water-tank fatigue tests at Toulouse—which had now shown that the Caravelle should be satisfactory for a life of 30,000 hr in Air France service. During last year cold-weather trials—including tests on snowy runways—were undertaken in Sweden. At the moment the eleventh aircraft to be produced was undergoing tropical trials and was shortly to be tested at high airfield altitude and high temperatures in Nairobi. There was good hope that estimates of performance under these conditions had been over-pessimistic.

The New Caravelles

All aircraft were at present fitted with Rolls-Royce Avon 522s of 10,500 lb thrust, and were known as the Caravelle Mk 1. They had a maximum take-off weight of 97,000 lb and a full-payload range of 900 n.m. with no wind and on a standard day. These Mk 1s could and would be modified to take the more powerful 11,400 lb-thrust RA.527s, which were soon to be delivered and which, when retrospectively installed, would convert the Mk 1s into Caravelle 3s. The take-off weight would go up to 99,210 lb and the range to 1,100 n.m., with the same take-off run as the Mk 1—5,900ft. Air France expected to have converted all its Caravelles to RA.527 power by the end of 1960.

Next to be developed would be the Mk 6. This would be fitted with Avon 531s of 12,000 lb thrust each and would improve maximum take-off weight (to 103,000 lb) and range (to 1,350 n.m.), although against this would have to be offset a conversion cost of about £25,000 for changed wheels and brakes and minor structural stiffening. The most developed version at present foreseen was the Caravelle 7, powered by Rolls-Royce RB.141s. This was not a conversion but a new aeroplane. Additional structure would have to be incorporated and the gross weight would go up to 110,000 lb. Full payload range would be extended to 1,970 n.m., with greatly increased cruising speed. The Mk 7 would also have a much wider choice of cruising altitude than its predecessors and would be more flexible in operation; but it was a remarkable fact, said M. Péan, that calculations by the S.B.A.C. formula showed operating costs of the different marks of Caravelle to vary by less than one per cent. The greater speed and better economy of successive marks was exactly offset by the combined cost of conversion and the increasingly higher cost of engines. Nevertheless, each mark became competitively much more attractive as range and speed increased and should provide Sud-Aviation with good prospects of further sales.

Discussing Air France's experiences with the Caravelle, M. Péan divided his comments under ten headings, as follows:—

(1) **Engineering, Maintenance and Servicing.** This had been much better than the airline's piston-engined aeroplanes and engine failures had been at the rate of 0.7 per 1,000 hr against 2.9 for piston-engined aeroplanes. Better regularity had been achieved and many fewer spares were required, and this was reflected in the economy of the operation.

(2) **Starting.** Ground starting carts providing 115V D.C. were not readily available on Air France's routes and were expensive. But up to three consecutive starts on the aircraft batteries had been proved possible.

(3) **Electrical Equipment.** Now that a good deal of new electrical equipment had been added the Caravelle was becoming relatively marginal on electrical power.

(4) **Hydraulics.** Lockheed Servodynes were working "quite well." A lot of difficulty has been experienced with pipes, as a result of excessive pressures, but a change to stainless-steel pipes had in general cured the trouble. Pressure regulators (similar to those on the Viscount) had given trouble, but this was probably because they were now leading a more arduous life.

(5) **Brakes.** These had, perhaps, been the most troublesome feature of the Caravelle. Because there was no thrust reverse, landing on a wet runway had caused some difficulties. There had also been difficulties with Maxaret units, but these had been overcome by changing the piping. Air France had embarked on a programme of re-educating their crews on the best use of brakes, but all Caravelles were now to be fitted with braking parachutes.

(6) **Structure.** The only trouble that had been encountered were small cracks in the tail and in the flaps, some of which may have been caused by sonic effects.

(7) **Servicing.** "No airline," said the lecturer, "is ever really satisfied."

(8) **Operations.** In timetabling, 30 min had originally been allowed for starting up and taxying, but experience showed that this could now be reduced to 15 min. With such fast block-times delays were very critical. Other points made by M. Péan were that temperature forecasting in Europe had not always been very good, that a Caravelle simulator had been ordered but not yet arrived, and that two-crew operation seemed to be satisfactory. Pilots had asked for larger cockpit windows and these might be incorporated in later marks. Special planning charts prepared for each route served by the aircraft had helped to simplify flight planning and operations.

(9) **Noise.** Take-off (as with all jets) was critical, and the Caravelle had to be operated in conformity with the procedures which reduce airport noise. The Mk. 1 had been shown not to need a noise suppressor but both the Mk 3 and Mk 6 would be fitted with the type developed for the Comet; RB.141 engines were said to have "no noise at all."

(10) **Air Conditioning.** This had proved satisfactory in service but internal ground temperatures in high or low ambients were being investigated to see if improvements could be made.

In general, M. Péan concluded, the Caravelle was a success—for Sud-Aviation, for Air France and for S.A.S.: "Passengers are satisfied with it, and so are we." He thought that further sales prospects were good, particularly for the RB.141-powered Caravelle 7.

Aircraft-mile costs were low because first cost was low and there were only two engines. The appeal of the Caravelle would be judged by the clock; it was fast, and it was as safe as any four-engined aeroplane. Its approach speed would permit it to use the same airfield minima as any piston-engined type; there was no justification for raising these limits because it was a twin.

The Discussion

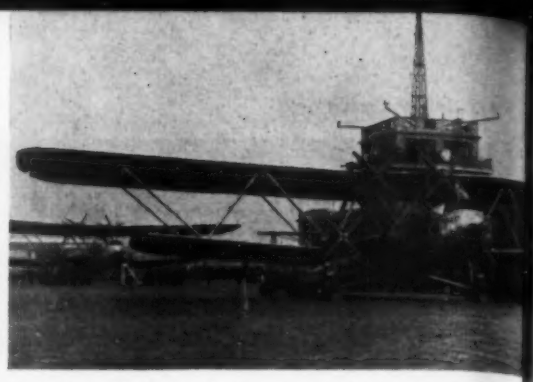
Opening the discussion, Mr. Beverley Shenstone, chief engineer of B.E.A., commented that no greater compliment could be paid to the Caravelle than to say that it had many imitators.

The first question which M. Péan dealt with was: "To what extent did Air France interfere with the manufacturer's choice of systems?" The reply was that while there had been very close co-operation with Sud-Aviation in deciding what systems to use Air France regarded the basic responsibility as being that of the constructor. In detail Sud had profited by Comet and Viscount experience.

Another question concerned the disadvantages of rear engines. Had Air France experienced, the questioner asked, difficulties in loading, or in trimming the aeroplane? M. Péan replied that difficulties had been few. The rear engines meant that the wing was placed well back and the tail area was thus relatively large, but the c.g. range was good and the only trimming problems that had been experienced were in mixed-class configurations where, for example, there had been no first-class passengers. The rear-loading door had been no trouble and was, he thought, more advantageous than inconvenient. The only snag that he could think of was that the galley was situated at the rear of the cabin and—because of the position of the engines—could have no separate servicing door.

THE SHEIKH STAYS IN

THE disagreement between Middle East Airlines and B.O.A.C., recorded last week, seems to have been patched up after discussions between Sheikh Najib Alamuddin, chairman of M.E.A., and Sir George Cribbett, deputy chairman of the Corporation. At any rate, there is now no likelihood that B.O.A.C. will relinquish its 49 per cent holding in its associate. The Corporation has agreed—subject to Treasury approval—to lend to M.E.A. an additional £1,130,000 for use as active capital, and to combine this new loan with the previous £5m funding and equipment loan at a "moderate" rate of interest (estimated to be about 4¼ per cent). In addition, the airline now have an assurance that B.O.A.C. will help secure for them modern equipment "for service next year." New aircraft with which M.E.A. could meet economy-class competition in the Middle East during 1960 was among Sheikh Alamuddin's major anxieties when he came to London last month: last week he was able to say in Beirut that the future of M.E.A. was now "safe and secure."



Left, the Croydon Airport clock says 6.30 p.m., and the last service out of the airport (see news-item below) prepares to depart. The heyday of the era which was thus ended is recorded in the "Flight" picture on the right, taken a quarter of a century ago, of H.P.42s of Imperial Airways

AIR COMMERCE . . .

LIGHTS OUT AT CROYDON

ON the same day (Wednesday, September 30) that Miss Jayne Mansfield opened in London the Ministry of Transport and Civil Aviation's latest road improvement—the Chiswick Flyover—the same Ministry closed Croydon, its most historic airport.

The log of movements for the last day showed an exodus of 29 assorted aircraft, the largest being a privately owned U.S.-registered Catalina. Others had previously been moved to new bases, notably the Shell International Petroleum Company's fleet, which in future is to be maintained by Morton Air Services at Blackbushe.

Quite a large but rather subdued and silent crowd gathered for the departure of Croydon's last scheduled service, operated by Morton to Rotterdam with Heron G-AXOL. With Capt. Geoffrey Last appropriately in command, R/Offr. M. P. Duignam and nine passengers, the Heron took off at 1835 hr and passed over the tower in salute (returned by the watchers below, including Capt. "Sammy" Morton himself) before setting course. The passengers had been suitably toasted in the Airport Club bar before embarkation—but different treatment was later meted out to an effigy, alleged to be of the Minister, carried in a coffin in solemn procession.

Morton Air Services and Olley Air Service will in future operate from Gatwick as their London terminal, keeping their Croydon office open for bookings, but carrying out major maintenance at Redhill. Adequate hangar accommodation will, however, shortly be ready at Gatwick.

Gatwick is, of course, the new home of most of Croydon's tenant companies, with the clubs and other companies already installed at Biggin Hill. But Mr. E. E. Ford, who remains as executive officer-in-charge at the airport, explained that the Civil Aviation Communications Centre, Field Aircraft Services, the Rollason companies, Marconi and the Ford Motor Company's shops, would continue their activities at Croydon. Although flying has ceased, the entire area of the airport remains Crown property until further notice, and the M.T.C.A. is responsible as before for its administration, maintenance and security.

For the record, the very last aircraft movement was that of G-AJWE, a Gemini flown out by C. J. de Vere at 1945 hr to Gatwick. The airport lighting came on as usual at dusk, but at 2230 it was "Time, gentlemen, please," and even the rotating beacon was doused. Croydon Airport's familiar outline was darkened, presumably for ever.

NORTH ATLANTIC SPRINGBOARDS

THE two most westerly international airports in Europe—Shannon and Prestwick—are both in the process of extension to a size that will make them suitable for jet transports. From a strictly air transport point of view, the expenditure of time and money on additional concrete and handling facilities may be hard to justify, particularly in the case of Shannon, which is now regularly overflown by the North Atlantic services of most European airlines. But if these airports are to continue in existence at all—and it is in Scotland's and Ireland's national interest that they should do so—they must either expand sufficiently to attract traffic, or lose their usefulness altogether.

In September the Ayr County Council accepted proposals for making an immediate start on the development of Prestwick's runways from 7,500ft to 9,800ft, and this work should be completed by June next year. The decision has been "warmly welcomed" by the Minister of Transport and Civil Aviation and a £240,000 contract has been let to Richard Costain Ltd. The extension, which will be at the seaward end of the present main runway, will include new perimeter tracks. Progress has also been made in planning the new terminal building which it is proposed to construct on the south side of the extended runway and adjoining the railway. Decisions on dealing with traffic on the road at present crossing the runway have been deferred until a new by-pass road is completed, but the possibility of a road tunnel under the runway is apparently still the subject of consideration.

The Irish Government, who have invested over £6 million in Shannon, have decided to improve facilities there in the hope of attracting more business. A new 10,000ft jet runway, 06/24, should be ready for service in July 1960, soon after completion of the new runway at Prestwick. A new terminal building, control tower, and hangar costing £1¼ million have been partly completed this summer.

During 1958, there were 14,500 aircraft and 505,000 passenger movements through Shannon and the Duty-Free Shop earned over £1 million, whilst terminating traffic is estimated to have earned the airlines about £3½ million. At the moment, B.O.A.C., Irish, Lufthansa, PanAm, Swissair and T.W.A. route passenger flights through the airport, whilst Seaboard and Western have chosen Shannon as their main base in Europe, both for freight-handling and maintenance. About 40 per cent of the Irish Air Lines traffic consists of passengers embarking or disembarking at Shannon, and they are winning almost all of the Irish-originating traffic and much of the terminating traffic from their competitors. Landing and handling charges for a Super Constellation total £114, and the break-even figure for a Shannon landing en route for North America requires a minimum uplift of five passengers.

The Shannon Free Airport Development Company (wholly owned by the State) has three main aims: to increase terminal traffic; to promote industrial activities for which air transport is suitable; to develop air-freight business generally. They are optimistic that when the new runway becomes operational and Irish Air Lines take delivery of their Boeing 720s in late 1960 other operators will use Shannon on their scheduled North Atlantic services. Shannon was the first Customs-Free Airport in the world in 1947 and the Development Company have three sites within the free-zone available for factory development and, in fact, they expect to have about twelve factories in production by late 1960. Powerful incentives to North American and Western European manufacturers are a 25-year tax-free concession on export profits, State assistance with premises and Imperial Preference rates on goods exported from Ireland to the United Kingdom and British Empire. The Free Port Cargo-Transit warehouses enable consolidated consignments from North America to be broken down at Shannon for delivery to various parts of Europe, and vice versa to the west.

VC.11 FOR CANADA?

PRODUCTION of the short-range VC.11—Vickers' "small" jet (see *Flight* for August 28, p. 92)—may, it seems, depend upon political issues. If Treasury support for new civil projects is forthcoming, Vickers may decide to go ahead without a domestic order with one or other of a number of designs which now comprise the embryo VC.11.

Unlike the Viscount, the Vanguard and the VC.10, each developed to a Corporation specification, the VC.11 may thus be developed as an optimized design that would best suit the collective needs of the airlines that are now writing their specifications for a short-medium range jet. Airlines interested are known to include United, Continental and Commonwealth operators, and a newspaper report last week referred to a promise by Canada—presumably T.C.A.—to consider the VC.11 without a British order. Thus Trans-Canada Airlines could once again be the means by which a Vickers aeroplane achieves an *entrée* to wider U.S. markets, and it seems likely that the design will be "North-Americanized" from its inception.

Nevertheless, the general configuration of the VC.11 is to conform to the European pattern of a clean wing and aft divided-flow engines as a means of achieving operational flexibility. It will be cast in a smaller mould of the VC.10 and it will be powered by four engines, presumably of lower thrust than the 10,000 lb of the RB.163 (yet another Rolls-Royce by-pass?). It has been said that the VC.11 could be ready for service within four years of receiving the first order; in spite of VC.10 and Vanguard production, construction space would be available at Weybridge.

A.T.C ABC—

JUST published* is a new tool of U.K. air transport, an official manual of air traffic control for the United Kingdom. It will no doubt become the *Air Pilot* of the professional air traffic control officer, but it will be of value also to everyone in the business who from time to time needs A.T.C. information of the kind which now takes a good deal of special research. For example, what special procedures are now in force for turbine aircraft? The answer can be found in Section 3. What are the procedures prescribed for Royal flights? Paragraphs in Section 2 refer. What are the precise standards laid down for vertical and horizontal separations—the essence of A.T.C.? Other paragraphs in Section 2 refer. What are the R.T. phraseologies for take-off, approach and landing, etc.? Section 6 refers.

The manual, available from H.M. Stationery Office, is actually Part 1 of three parts, Parts 2 and 3 (which are not on sale) containing air traffic control instructions of more local and area interest.

Part 1 is divided into ten sections, as follows: (1) Definitions and Abbreviations; (2) Standards and Procedures—General; (3) Procedures—Aerodrome and Approach Control; (4) Procedures—Area Control; (5) Procedures—Radar; (6) Procedures—Communications; (7) Special Administration for A.T.C.O.s; (8) Not allocated; (9) Not allocated; (10) Supplementary Procedures.

Not included, though these might well be of considerable reference value, are maps and charts of the U.K. airways and traffic control system. Otherwise there is very little in this new document that those concerned with United Kingdom A.T.C. will fail to find. An amendment service is obtainable on payment of £1 deposit.

Enquiries should be addressed to the Secretary, Ministry of Transport and Civil Aviation, 19/29, Woburn Place, London, W.C.1.

*"*Manual of Air Traffic Control." Price £3 5s, H.M. Stationery Office, P.O. Box 569, London, S.E.1.*

—AND AIRPORTS ABC

OF more popular appeal, but in its own way just as thoroughgoing, is an excellent little reference-booklet† to Britain's airports in the A.B.C. series. Compiled by John W. R. Taylor, it offers a compact description of 41 airports in the British Isles, providing a map of each one, salient data and a brief history. It is also illustrated with photographs of airports and of the airliners which use them. A table, based on M.T.C.A. statistics, analyses aircraft, passenger, freight and mail movements airport by airport, and an appendix lists the current fleets of Britain's independent airlines. It should be a useful reference for people in the business as well as the public.

B.A.L.P.A. v. B.E.A.

THE patience of the British Air Line Pilots Association with B.E.A. is "wearing a bit thin," comments *The Log* in an editorial reviewing the long negotiations (through the established N.J.C. machinery) over a pay claim lodged by B.A.L.P.A. with the Corporation. The Corporation's B.A.L.P.A.-member pilots are "greatly disturbed" at the deterioration in relations.

Last July the B.E.A. flying staff magazine *Intercom* published a personal letter which Mr. A. H. Milward, B.E.A. chief executive, had written to B.A.L.P.A.'s general secretary, Mr. D. Follows. This complained that the June issue of B.A.L.P.A.'s *The Log* had published a "depressing catalogue" of management-pilot differences, without "chronicling the real achievements."

Unfortunately, Mr. Follows had not given his consent for Mr. Milward's letter to appear in *Intercom*, and this caused a certain amount of embarrassment to B.E.A. However, *The Log* itself now reproduces Mr. Milward's letter, and Mr. Follows' reply to it. He says that he cannot think of any real negotiation achievements; and it seems that the B.A.L.P.A. pay claim on behalf of B.E.A.'s pilots remains in the negotiating stage.

†"*British Airports*," by John W. R. Taylor, from the A.B.C. series of publications by Ian Allan Ltd., Hampton Court, Surrey. Price 2s 6d.

BREVITIES

Just received from I.A.T.A. is a second edition of *Airport Buildings and Aprons*. It is hoped to review this revised guide to airport planners in an early issue.

A four-engined Soviet jet aircraft designated "201" is claimed to have carried a load of 10,000 kg (22,046 lb) up to 50,000ft on September 16. This has been submitted to the F.A.I. as a world record.

The managing director of J.A.L., Mr. Kinjiro Yuchi, says that his airline is planning to increase its order for four DC-8s to six. First aircraft of the original order is due to be delivered in May 1960.

Sabena will inaugurate Boeing 707-320 services between Brussels and New York on February 15. There will be four flights weekly. On the same date 707s will inaugurate a weekly service to Leopoldville via Rome.

November 24 is the date set by T.W.A. for the introduction of Boeing 707-320 Intercontinentals into North Atlantic service between New York and London. Initial frequency will be three times weekly.

Intercontinental Boeing 707-321s are to be introduced on to PanAm's London - New York services from tomorrow, October 10. Flights with the -321s will reach a frequency of two per day by December and are to take 7 hr 35 min westbound and 6 hr 24 min eastbound.

Two types of jet transport are reported to have been selected for development from 13 designs for a West German airliner. A bill which would enable production to proceed is now under preparation by the West German Economics Ministry.

L. W. Hartman and R. W. Clifford, respectively executive vice-president and vice-president of operations, Lake Central Airlines, have recently visited Fairey to discuss the Rotodyne and A. V. Roe and Rolls-Royce to discuss the Avro 748.

Varig have received their first Sud Caravelle and Air France their sixth. This month S.A.S. will receive its fifth aircraft and in November and December further deliveries will be made to Air France, S.A.S. and Varig. The first aircraft for Air Algerie will be delivered in February.

Loans so far approved by the ExIm Bank, according to *Aviation Daily*, are as follows: $15.7m to Alitalia (four DC-8s and spares, total cost about $24m); $6m to T.A.I. (two DC-8s); $46m to Air France (17 Boeing 707s); about $17m to J.A.L. (four DC-8s at $22,910,000, the balance to be financed by Douglas). Interest rates on most ExIm Bank loans have been 5¼ per cent; the J.A.L. loan is at this rate over 7 years.

Changes have been made in the Caravelle/Convair jet fleet of the S.A.S.-Swissair consortium. S.A.S. has increased its Caravelle order from 16 to 17, four of which will be leased to Swissair. Delivery of the seventeenth aircraft is scheduled for January 1961. Swissair confirms that its order for five Convair 880s has been changed to an order for seven Convair 600s, to be known as Coronados (*Flight*, August 14) two of which will be leased to S.A.S. for four years. The seven 600s are scheduled for delivery by the spring of 1961.

B.O.A.C.'s DC-7C utilization reached a new peak of 11 hr 37 min per aircraft per day in the four-week period ended September 19.

General Loginov, head of Aeroflot, said in New York last week that the U.S.S.R. were prepared to begin operating into New York and would welcome American jets into Moscow: the problems were diplomatic, not technical.

Mr. Donald Finlay of Boeing is reported to have said in recent talks with K.L.M. that no decision had yet been made whether the 727 short-range jet would have two, three or four engines. Passenger accommodation would be 65-75.

K.L.M. will inaugurate Electra services on December 15 on the route Amsterdam - Dusseldorf - Vienna - Istanbul - Ankara - Cairo, replacing DC-6Bs. The Electra will also be used on the route to Damascus and from January 15 on that to Teheran.

It is reported that Capital Airlines, who have an option on six Convair 880s, are now showing interest in the Boeing 720. It is understood that the way is now open, as a result of satisfactory negotiations with the British financial interests involved in the airline's Viscount commitments, to place an order for new equipment.

The New Zealand Minister of Civil Aviation, Mr. John Mathison, says that N.Z.N.A.C. will decide on its DC-3 replacement before the end of 1959. The airline, which has recommended the purchase of four Friendships (*Flight*, September 25), would make a further appraisal after the appearance of the Dart Herald and the Friendship at the opening of Wellington Airport on October 24.

Talks between the civil aviation authorities of India and Australia (see Pan Commonwealth Airlines?, *Flight*, September 18) opened in New Delhi on September 29. An Indian correspondent reports "fundamental differences" in regard to the provisions in the bilateral regarding frequency and capacity. The Indians are said to be seeking pre-determination of capacity: a pool agreement is being discussed.

A B.O.A.C. Boeing 707-420 on a manufacturer's test flight covered 4,815 miles non-stop from Seattle to Tokyo last week. Take-off weight was 302,000 lb and flight time was 10 hr 55 min with sufficient fuel for 90 minutes' cruising remaining in the tanks at Tokyo. Average headwinds were 85 m.p.h., and for one hour headwinds of more than 200 m.p.h. were experienced. There were 57 people on board, including Mr. Grant McConachie, president of C.P.A.L.

According to M. Georges Hereil, president of Sud-Aviation, cost of a tail braking-parachute for the Caravelle is $16,000 (£5,700), compared with an alternative cost of engine thrust-reversers of $60,000 (£21,400). A note on Caravelle braking experience appears in an article on page 353. M. Hereil says also that an order from a U.S. airline is expected soon (United?) and that current price of the Caravelle 3 is about £950,000 less spares and U.S. duty. Break-even point is about 200 aircraft, an increase from the original estimate of 150 as a result of increased costs. A cargo version, to be sold at a lower price, is soon to be offered.

THE ANGLO-AMERICAN CONFERENCE (continued from page 347)

Two varieties of VTOL aircraft, he said, existed—the "tailsitter" and the "flatriser." Rolls-Royce were concerned with one U.S.-sponsored tailsitter, but their primary thinking had been "around the flatriser."

The history of Rolls-Royce jet-lift development began in 1949, said Mr. Pearson, when they commenced to build small jet engines intended for powering guided missiles. Their first attempt was the RB.82, a simple axial-compressor unit of 4.5 compression ratio which had many novel mechanical features designed to ensure low weight. The combustion chamber was of special advanced design—rather too much so, because it seriously hampered the engine's ability to function properly during starting and low-speed operation. It was of interest, said the lecturer, that "we are now testing combustion chambers of similar standard to the initial design, so we must presume that we were ten years too far ahead!"

A development of the initial engine was the RB.93 Soar, some of which had been fitted to Radioplane-built (U.S.) target drones. Further work led to the construction of the Nene-powered "Flying Bedstead." Although this rig was fairly easy to fly in pitch and roll, height control presented some problems. The motions required to control the aircraft in ascent and descent were by no means instinctive, and laboratory-conducted simulator experiments indicated that nearly all "learners" would crash the aircraft on their first attempt. However, as a result of the test programme, it was decided to proceed with the design of a special vertical jet-lift engine of small size and thrust.

The RB.108 engine resulted from the subsequent work, and five of these engines were now installed in the Short SC.1. Four units provided 8,600 lb total lift thrust, while the fifth engine, a "special propulsion engine without 10 per cent bleed air" was arranged in the rear fuselage, for forward propulsion. The SC.1 had successfully hovered for periods up to six minutes, and it was expected that transition testing would be initiated during the present year. Future development of jet-lift engines held the promise of reducing engine specific weight from the 0.112 of the RB.108 to a value of 0.06. This specific weight could probably be realized up to a thrust of about 5,000 lb.

Mr. Pearson concluded his remarks by noting the tremendous savings —particularly in airfield costs—possible with VTOL-type aircraft.

Opening presentation scheduled for the morning of October 6 was a paper entitled *The Behaviour of Supersonic Boundary Layers in the Presence of Shock Waves*, by G. E. Gadd and D. W. Holder, of the National Physical Laboratory. The topics covered in their highly technical—but informative—paper were: (1) Calculations by the Crocco-Lees method of interactions between shocks and laminar layers; (2) the effect of large rates of heat transfer on the pressure distribution through a region of laminar separation; (3) laminar separation on thin axi-symmetric bodies; (4) skin friction and heat transfer in turbulent separated regions; (5) the upstream influence in interactions between strong oblique shocks and turbulent layers; and (6) interactions between weak normal shocks and turbulent layers.

Work of the B.L.E.U.

Also being presented during the morning was a paper by W. J. Charnley, superintendent, Blind Landing Experimental Unit, R.A.E., on the subject of *Work of the Blind Landing Experimental Unit*. Describing the Unit's function as the development of aids to enable military and civil aircraft to land under all weather conditions, the paper explained that the work embraced all aspects of the problem.

It was sometimes argued that there was no further need for improvement in landing aids because the number of occasions on which the weather fell below current acceptable landing limits were too few to justify the extra complication and expense of developing and installing new "black boxes" in aircraft. This argument could be refuted. In Europe, more than 3 per cent of all scheduled landings by one of the principal airlines had to be cancelled during the winter months owing to bad weather. Such a record could have a serious effect upon the overall economy. In the three months from November 1958 to January 1959 the weather at London Airport was below minimum (200ft and 400 yd) for 13 per cent of the time. And there could be no doubt that the overall weather problem would become more critical in the future, for several reasons: (1) as the design speed of an aircraft increased, existing standards of safety could be maintained only by raising the operating limits and hence reducing regularity even further; (2) as traffic density increased, missed approaches would have to be reduced to a minimum; and (3) because the penalty of carrying large fuel reserves in supersonic types was severe, the feasibility of faster-than-sound airliners might well hinge on their ability to land at the destination on time and on the first attempt—"The case, therefore, for being able to land at an intended destination not only in weather worse than is permitted by current minima, but even irrespective of weather, is overwhelming." Mr. Charnley's paper next discussed a fully automatic system with which the R.A.E. had been experimenting for some time. It used the internationally accepted radio approach and I.L.S. to the point where more accurate information was required, and then added two new elements for the final landing. These elements were a magnetic "leader cable" for azimuth landing guidance and a radio altimeter for vertical landing guidance. The former device provided accurate (±5ft) azimuth guidance whose data was linear in character and hence independent of range. The special radio altimeter provided, with a very small time-constant, an accurate and "clean" height signal suitable for differentiation. About 3,000 safe and successful landings had been made with the system in all weathers in both propeller-driven and turbojet-engined aircraft without any damage whatsoever.

On Tuesday afternoon Mr. Bernard O. Heath, assistant chief engineer, English Electric Aviation Ltd., was presenting a paper, *Design Philosophy for High Acceleration and Temperature*. This pointed out that developments in propulsion and aerodynamics now permitted flight in a speed range which added the problems of elevated temperatures to existing problems; however, aircraft had been successfully produced for many years with simplified representations of actual conditions, and consequently the treatment of new problems (such as heat) must not be over-meticulous to the detriment of provision against existing ones.

A treatise on *The Future of Automatic Control of Fixed Wing Aircraft* by G. A. Whitfield, professor and head of the Department of Aircraft Electrical Engineering, College of Aeronautics (Cranfield), was scheduled to follow. In it Prof. Whitfield noted that aircraft were traditionally designed so that their handling characteristics were acceptable when all auto-controls were inoperative. The aim was to produce an aircraft which was "nice to fly" under those conditions. Auto-stabilizers were used to improve the characteristics still further. This attitude could be compared with the practice in guided-missile design, wherein little consideration was given to characteristics of uncontrolled vehicles. Control and aerodynamic characteristics were considered jointly in the guided weapons field to attempt to produce the most economical design of the controlled vehicle. "Perhaps it is now time to consider whether or not the auto-controls should be regarded as an essential part of a manned aircraft, which would be designed on the assumption that it would always fly with the auto-controls in operation." Difficulties would arise if auto-controls failed—the aircraft would then be uncontrollable—but it appeared practicable to develop automatic controls for aircraft which were sufficiently reliable for the safety of the aircraft to depend upon their operation.

The advantages to be gained by acceptance of such an idea, and the development of the necessary equipment, would perhaps be in safety. Many "pilot error" accidents might be eliminated. Another advantage would be that of confidence in the ability to land at a specified airfield. A third advantage would be freedom of design "if inferior stability characteristics were accepted."

The opening paper on Wednesday morning was being presented by G. V. Bull, superintendent of the Aero Physics Wing of the Canadian Research and Development Establishment. Entitled *Re-Entry Studies in Free-Flight Ranges*, the work described the free-flight range of the establishment along with its instrumentation, and presented details of studies conducted thus far. A gas gun launcher was employed to fire models of varying size (from a fraction of an inch to an inch in diameter) through typical re-entry Mach Number ranges. The model's flight was through a long evacuated tube whose internal pressure was reduced to simulate high altitudes. Short-duration spark shadowgraph techniques were utilized for viewing the flight with optical equipment. Microwave spectroscopy was employed to determine the surrounding field and wake characteristics. Simple telemetry was used.

Unresolved Civil Airworthiness Problems, a paper by Walter Tye, chief technical officer of the A.R.B., was also being presented in the morning. Admitting that correct conclusions had to be drawn from inadequate data in too short a time, the paper stated that the final test of soundness of airworthiness requirements was operational experience. If it were possible to delay airworthiness decisions until such experience had been gained, the task (of the airworthiness engineer) would be relatively simple. But since these delays were not permissible, the airworthiness engineer had to strive to foresee eventualities as each new generation of aeroplanes appeared. The airworthiness level could be raised or lowered at will by greater or less expenditure of money and manpower, and the number of proving flights made with an aircraft were examples of this principle. In virtually all new aircraft teething troubles were encountered. The amount of teething problems discovered and cured before an aircraft entered scheduled service was directly related to the amount of proving accomplished with the aircraft.

Route-proving Cost

However, the obvious objection to extensive route proving was its enormous expense, "not only direct but in terms of the time lost before delivery." For example, if 20,000 hours were a necessary "settling period," the cost of such proving flights would be equivalent to the purchase price of 20 aeroplanes. It was evident, therefore, that unless very large production lines were envisaged, the costs of proving flying at that order were likely to be resisted with great vigour.

A means must be found to achieve reliability at an early stage, and one of the ways to achieve this objective was through more extensive ground-rig testing. The use of simulators might also help to uncover the operational problems which arose due to unforeseen behaviour on the part of the flight crew.

H. Metcalfe, chief aerodynamicist, guided weapons, Bristol Aircraft Ltd., was the author of a paper entitled *Some Considerations of Stability and Control for Hypersonic Vehicles*. Although the aerodynamic design of hypersonic vehicles was receiving much attention, analysis of stability and control problems of hypersonic types had been treated heretofore with secondary importance (to the problems of aerodynamics and heat). "It is my thesis that the stability and control problem is likely to be of a difficulty far exceeding that of conventional aircraft and the designer is not provided with sufficient (data?) for design decisions to be convincing." Mr. Metcalfe then discussed various possible types of configurations for hypersonic flight and then discussed the relative stability of several vehicles.

With the reading of the final papers the meeting was due to be adjourned; however, many of the participants were likely to remain in the hotel to attend the conference dinner and awards presentation in the evening of Wednesday. The presentation of the Elmer Sperry Award was scheduled to be made to the de Havilland Aircraft Company to Sir Geoffrey de Havilland for his leadership as president of the company, to Mr. C. C. Walker as technical director and chief engineer, and, in memoriam, to Major Frank Halford, as chief engineer and technical director of the de Havilland Engine Company. Guest of honour at the banquet was to be Sir Geoffrey de Havilland.

(To be continued)

British Equipment and its Manufacturers*

Ground Communications Equipment

U.H.F. transmitters (4 to 20 W)	Elliott, G.E.C., Pleasey, Pye.
U.H.F. receivers	Elliott, G.E.C., Pleasey, Pye, Stratton.
V.H.F. transmitters (15 W to 1 kW)	B.C.C., Ekco, G.E.C., Marconi, Pye, Redifon, S.T.C.
V.H.F. receivers	B.C.C., Ekco, G.E.C., Marconi, Pye, Redifon, S.T.C., Stratton.
H.F. transmitters (30 W to 4 kW)	G.E.C., Marconi, Mullard, Pye, Racal, Redifon, S.T.C.
H.F. receivers (fixed and tunable)	Airmec, G.E.C., Marconi, Mullard, Pleasey, Racal, Redifon.
Ancillary Ground equipment:	
Multichannel recorders	B.C.C., Thermionic Products, Simon.
Beacon monitor receiver	International Aerodio.
Life-saving beacons	Burndept, Ultra.

Ground Radio Aids to Navigation and Landing

Area-coverage radio nav. systems	Cossor, Decca.
Direction finders	Ekco, Marconi, S.T.C.
Non-directional beacons	G.E.C., Marconi, Redifon, S.T.C.
Instrument landing systems	Pye, S.T.C.

Ground Radar Aids to Navigation and Landing

Primary surveillance radar	Cossor, Decca, Marconi.
Secondary surveillance radar	Cossor.
Secondary radar, D.M.E.	Murphy, S.T.C.
Precision approach radar	Ekco, S.T.C.
Height-finding radar	Decca, Marconi.

CONTENTS

What Do We Do Now?	358
Developments in Aviation Electronics	361
An Airline's Attitude to New Electronic Equipment	365
Military Electronics	366
Computers: Digital and Analogue	370
Computers in Aviation	373
Aircraft Communications	378

Ancillary Ground Radar Equipment

Weather-finding radar	Cossor, Decca.
Meteorological radar	Decca, Marconi.
Airfield surface movement indicator	Decca.

Airborne Communications Equipment

H.F. Trans/receivers (100 to 130 W)	Marconi, S.T.C.
V.H.F. Trans/receivers (1.5 to 25 W)	Burndept, Elliott, Marconi, Murphy, Pleasey, S.T.C., W. S. Electronics
Teleprinter receivers	Marconi, S.T.C.

Airborne Equipment for Navigation and Approach

Secondary radar	Cossor, Murphy, S.T.C.
Area-coverage radio navigational	Cossor, Decca.
Doppler navigational	Decca, Marconi.
Weather radar	Ekco, Elliott.
V.O.R./I.L.S. receivers	Elliott, Marconi, S.T.C.
Automatic radio compass	G.E.C., Marconi.
Radio altimeter	G.E.C., S.T.C.
Search and homing receivers	Burndept, Ultra.

Computer Manufacturers

Associated Electrical Industries; Benson-Lehner (G.B.); Elliott Brothers (London); E.M.I. Electronics; English Electric; Ferranti; IBM United Kingdom; International Computers and Tabulators; Leo Computers; National-Elliott; Panellit; Saunders-Roe; Short Brothers and Harland; Solartron Electronic Group; Standard Telephones and Cables.

Flight Simulator Manufacturers

Air Trainers Link; Miles Electronics; Redifon.

*List compiled by International Aerodio Ltd.

Aviation Electronics

IN aviation, perhaps more than in any other field, the science of electronics has brought revolutionary changes during the past 20 years; and even now the full potential has by no means been achieved. The demand for electronic equipment of all kinds increases steadily; both military and civil users demand more and more assistance in performing special tasks, not only in navigation, communication and weapon control, but in aircraft systems of all kinds.

The critical element in these requirements is that no unnecessary inroads must be made into payload, and the extent to which the additional electronics can be introduced into aircraft—particularly airliners—is dependent to a considerable degree upon the amount by which equipment weights can be reduced. The new miniaturization techniques and components now emerging from the laboratories open the way to tremendous progress during the next decade. But this is only one side of the problem. Their introduction will require something like a complete reappraisal of maintenance techniques: some operators want replaceable modules, others want replaceable cases, and the ultimate goal seems to be the guaranteed-life case which can be discarded after a specified operating period.

New developments and requirements are extensively discussed in the succeeding articles, but perhaps the central theme is the ever-increasing use of computers for all kinds of applications. Each of these aspects of the subject could alone occupy this whole span of pages; but "Flight" has elected to summarize the overall situation, particularly in relation to commercial operation.

Do We Do Now?

IS IT TIME TO REAPPRAISE INTERNATIONAL STANDARDS?

WHILE there is no doubt that the British aviation electronics industry can produce both ideas and equipment fully capable of meeting international airline requirements, there is at the moment an increasing sense of frustration at the international obstacles which have to be overcome in introducing new systems. It is not simply a question of producing competitive equipment and selling it on its own merits. Whether we like it or not, the field is dominated by American production and standards, and many of the latter have been internationally accepted. Other equipment must conform to this framework. The British attitude, as recorded in *Flight* immediately after the I.C.A.O. meeting in Montreal last February, might now become increasingly one of implementing new systems locally, not so much in opposition to established standards but as an addition to them. The most difficult area is in navigation aids because on these the air traffic control system must ultimately depend.

The basic reason, *Flight* considers, is that decisions about radio systems requiring air and ground counterparts are in the end made internationally, and it can happen that an important development on which great resources and money have been spent over years is killed by a simple democratic vote. On the evidence of the last ten years or more of I.C.A.O. facilities standardization, the risks involved in this sort of endeavour are far too great; and the mood is growing that the chances of success are too slender to warrant the committal of large-scale development funds to projects on which an international decision will finally be made.

The most recent case in point is the Decca Navigator system. Under the very active encouragement of the British Government, this system has been under development for airline (and military) use for many years. I.C.A.O. has been kept informed of progress and has taken note of its existence, even if it has not encouraged continued development. Nevertheless, when it had been brought to today's stage of refinement after much development in large-scale operational use it suffered a summary fate because it was contending against Vortac of the U.S. "Common System."

The particular example of Decca is recent history and caused no real surprise. It was predictable because the final acts which are taken in I.C.A.O. are not the acts of an unfettered assembly of experts free to decide, on the merits of the case, what they must do to provide the facilities needed by aviation. Again, the reasons for this are well-known. To put it bluntly Montreal has become the annexe of Washington in the business of radio facilities standardization. Perhaps none of this would be so important were it not for the fact that it is having a highly stultifying effect not only on the question of navigation aids but also on the associated systems which depend so heavily on the type of navigational aid used. So it is worth examining the basic reasons for this impasse not only to understand it, but perhaps also to see if there is any real hope of changing it.

There is no simplicity about the processes by which decisions in these matters are made in Washington, but neither is there any mystery. Their aviation is vast and vital but above all it is composed of several disparate, influential elements, the main ones of which are the airlines, the military and what is called general aviation—the latter running the gamut from the smallest private aeroplane to the large corporation-owned airliner indistinguishable from that operated by the airlines. To give scale to this, the airline establishments aggregate perhaps 2,000 aeroplanes, the military perhaps twice as many; and general aviation is now quoted as approximately 70,000 aircraft. What proportion of the last-named flies airways or really contributes to the A.T.C. problem in acute areas is not known, but they all count in the pressure lobbies.

Shortly after the last war, at the dictates of the military authorities, the common system for the Federal airways of the U.S. became the nationally established policy of the U.S. In its simplest terms the common system requires that the navigation and communications aids adopted for the airways must be suitable not only for the needs of both civil and military transport movement but also for the tactical purposes of the military establishment. It is the adoption of this common system policy which has had the most far-reaching consequences, has dominated the business of international radio facilities standardization ever since it was made and has from the moment of its inception effectively shut the door on selection of world systems by true international process. Neither I.C.A.O. nor I.A.T.A. has been able to exert any real influence on these events. The whole aviation world was witness to the V.O.R. versus Tacan controversy, the eventual settlement between civil and military on the compromise Vortac and the subsequent appearance of the Tacan-compatible D.M.E. in I.C.A.O. for addition to the standards. The position taken by "general aviation" in these common system tribulations is very largely one of protecting the investments in airborne radio equipment. This naturally manifests itself today in strenuous resistance to any suggestion of abandonment of V.O.R. as the key radio facility. And in much the same way, when cheap, light radios appear on the market to suit the needs and pocket of the small aeroplane operator, the D.M.E. will also become immovably entrenched and will build one more barrier against change to better things.

It would be wrong to leave the conclusion that V.O.R. has not

(Left) Demonstration of Autoland, developed by B.L.E.U. in conjunction with Smiths, Standard Telephones and Cables, Murphy and Pye

An American F.A.A. representative examines the Decca Navigator installed in a Bell helicopter flying with New York Airways

been one of the valuable radio facilities in use in civil air transport today. It has served operations reasonably well, even in high-density areas, for some years and will continue to do good service in the simpler traffic complexes for many more years to come. But it is right to criticize the forces which made it the international standard and especially right to see whether there are any other ways by which the constraints imposed by the demands of the common system can be removed and the way opened to a fresh attack on the whole problem of facilities development.

For most of the radio facilities which support it, civil aviation is still relying on the spate of planning which was done in the immediate post-war years, finishing to all intents and purposes in about 1950. This period saw the birth of the plans for V.O.R., I.L.S. and V.H.F. communications and the subsequent years have refined them in the hard school of use. These basic facilities, and ground radar, have seen civil aviation through to the present. There is a growing realization that the subsonic era is not going to be very effectively served by stretching this phase of planning very much further. What is needed is a new spasm of systems planning—not to abandon the old, but to introduce the new as an essential overlay to confer on jet aircraft the freedom to operate safely in the way their special characteristics demand.

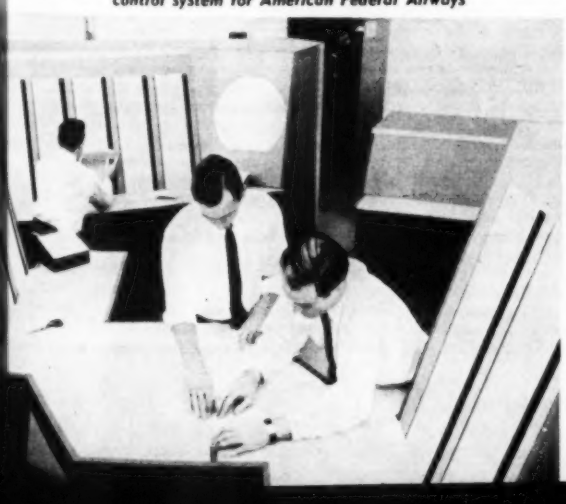
The F.A.A. has announced an immense programme of research and development on the widest possible front of attack on these problems. The National Aviation Facilities Experimental Centre at Atlantic City will be without doubt the largest and most powerful effort ever mounted for basic research and development in the air transport technical services; and when it gets into full stride it will accomplish tremendous things. It remains, however, purely domestic in concept and does not yet have any formal relationship with bodies outside the U.S. That it will be powerfully supported by the "avionics" industry in America goes without saying. From one or two recent statements, it may be taken that Mr. Quesada's policy for the F.A.A. development activity is going to be an "open door" one and outsiders who can help or who wish to see what is going on will be welcome. This is typical of the U.S. extrovert attitudes. But does it really go far enough?

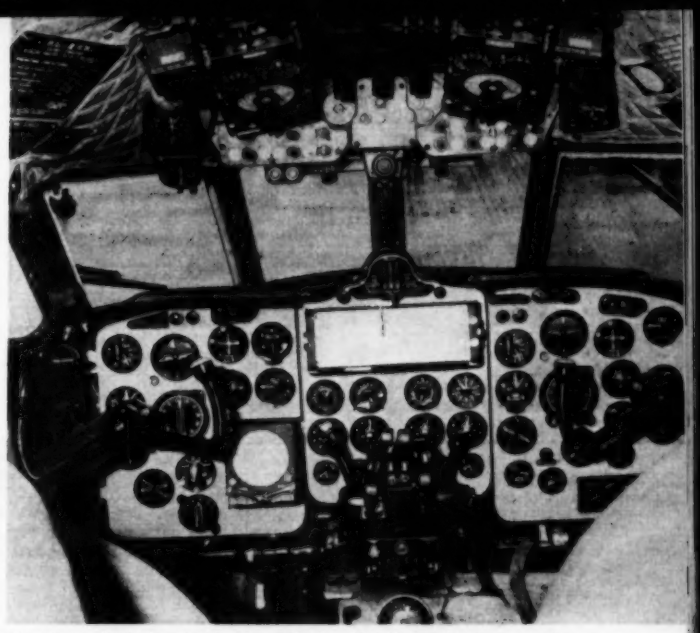
Mention has been made of the support which the U.S. electronics industry gives to Government development programmes of the kind to be carried out by the F.A.A. U.S. industry can do this by virtue of its size, because of the enormous sums paid out by Government for development projects and, not least important, by virtue of the fact that it has a pretty high assurance in advance that the end products of its developments are going to find useful commercial outlets not only in the States but also, because of the unique position of the U.S. in international circles, abroad.

By contrast, the British industry has been forced increasingly over recent years to undertake whatever civil work it seemed reasonable to do as a by-product of its military development contracts. Moreover, since it can look to comparatively small volume outlets within the U.K. it must look increasingly overseas to find the markets which are needed to justify the ordinary commercial risks involved in costly prime developments. And this is precisely where the international uncertainties bear most heavily.

Numerous products of British development activity—and this includes both Government establishments and industry—can lay proper claim to a number of valuable contributions and it is not necessary to go outside the electronics field to find them. Marconi's Wireless Telegraph Company were first in the field with an airborne Doppler radar truly designed for civil transport use, accomplishing this out of their extensive experience with military radars in the shortest possible time following the security release. Another example of equipment for the airline operator is the Ekco Electronics weather radar which is a very substantial advance in design over anything else on the market. In the systems field, the basic ideas underlying the I.C.A.O. secondary radar standards have come from Cossor Radar and Electronics as much as from anything done in the U.S.

Mock-ups of some of the control consoles for the great new traffic-control system for American Federal Airways





The Decca Flight Log in the Comet 2E in which Decca Navigator and Dectra were demonstrated during the I.C.A.O. meeting in February

The secondary radar example does, incidentally, point the value of trans-Atlantic industry partnerships when the necessary accompaniment of inter-Government agreement on policy is present. Yet another example of first-class systems engineering is Dectra, which is under operational trial on the North Atlantic as a result of joint Government-industry financing and technical resources. Conceived as a means for introducing a new accuracy into long ocean crossings, at the same time simplifying the flight-deck navigational work-load and above all making possible a proper height flexibility for turbine aircraft, Dectra is the only long-range system from any source which looks like being available in time for the need. It is indeed very fortunate that it is undergoing widespread airline trials before it comes to the international committee table. The sheer pressure of the need may ensure its survival.

Talking of systems, it is impossible not to mention once again the Decca Navigator itself. Surrounded by so much controversy as it recently was, it is not only the most highly refined navigation system in the civil transport business today, but is at the same time an embodiment of a different operational attitude to the problem of traffic control in the high density region. It is precisely because of this that it ran into a head-on collision with the U.S. viewpoint, which is and always has been dominated by the point-source aid. Whether Decca itself ever wins through to the international statute book or not, the ideas which it enshrines assuredly must if the available horizontal freedom of the airspace is ever to be properly used.

There are other examples of perhaps a less spectacular kind. Radar in the air traffic control services perhaps saw quicker progress at London Airport than elsewhere in the world. A wide diversity of specialized techniques has been worked out by industry in full collaboration with M.T.C.A. and the resulting data extraction, information transfer and environmental feature displays are in everyday use. By way of a final example, there is the B.L.E.U. work, fundamental both in its nature and its importance, in one of the toughest, because the most critical, phase of all—automatic landing.

Each of these examples, in its different way, breaks new ground in the radio technical field on a wide front of the problems which confront civil air transport today. All of them are evidence of a development vigour and a capacity for the generation of ideas, and they grow out of a national development activity in which industry and Government are inextricably associated. The problem is to find a way by which these resources can be unleashed on the common international needs of a civil air transport industry which enters the next decade with far more uncertainties about its technical services than did its piston-engined predecessor of 1950.

It is extremely hard to see that any change can be made now by any action which could be taken in Montreal. There is no separate authority in the international organizations in these matters which is not the authority of the member-States themselves, or in the case of I.A.T.A., of the airlines—who tend in these matters to become exponents of their Governments' policies. It is just conceivable that the very bitterness of the recent conference on short-range aids may in itself compel a

New radar control equipment under development by Marconi

AVIATION ELECTRONICS . . .

re-appraisal of the whole situation, if only because this conference has more than any other put into sharp public focus an issue which cannot be internationally healthy. The action of the Council next year may be one indication—although it seems very likely that it will pass D.M.E.T. into the I.C.A.O. standards.

Industry's own reactions to the international malady may be discerned in the growing tendency for individual firms to make the best they can of things by seeking liaisons, more or less formal, with American firms with whom they enjoy either traditional or natural affinities. Some of these liaisons are known to have been fruitful but, in addition they would be most valuable alliances of technical force if the objects for which they existed were truly international in character. Moreover, such relationships do not seem to hold much opportunity for prime development of systems because they can hardly contain any element of influence on the dominant Government planning machine. But these are at best the relationships of dependence.

No search for ways round the present problem, if one accepts the fact of its gravity, can ignore the very question of "standardization" itself: to ask in plain terms whether international standardization must retain the position of dominance it has had up till now. International standards exist to ensure that aviation will have the use of the same ground facilities wherever they are required in any part of the world, and that equipment specifications will be complete enough. The two factors together allow the operator to carry a minimum of airborne equipment on the world's air routes and to get uniform performance from it. This does, of course, paint an idealized picture; economic considerations alone prevent implementation from being other than patchy and the international operator still has to fit a variety of systems.

There are notable examples of "non-standardization." Australia herself departed from the international rule book by adopting her own D.M.E. standard in the late 1940s. It is important to note, however, that Australia never allowed this decision to affect the international carrier. Equally interesting is the fact that Australia shares with the United States the characteristic that both have a vast domestic air carrier industry which, comparatively speaking, dwarfs their respective international operations. The B.E.A. case provides another example. Their carriage of Decca in what were massive operational trials of that system were an effort to lead "standardization" along break-away paths by regional demonstration. It might have succeeded if the other influential European airlines had had an operating network similar to that of B.E.A. As it is, they had to look at their flight operations outside Europe at least as much as those they had within Europe and most of them had a more or less extensive U.S. operation. Leaving these examples aside, the pursuit of standardization has been a foremost consideration of the airline operator for reasons of weight-saving in the aircraft. Weight is still a vital commodity and in few cases do the electronics not eat straight into the payload. Nevertheless, it is a provocative thought that the striking reductions in the weight of radio equipment which have been made possible by the researches in solid-state physics are taking place at a time when the big thirsty jet is establishing itself in service. Big penalties are paid if these aeroplanes have to spend avoidable time in the air, do unplanned things or have to accept flight clearances which depart widely from the optimum. T.W.A. and other U.S. operators of the Boeing 707 have made their public complaints on this score and if Captain Masland's forecasts, given to the I.C.A.O. short-range aid meeting, are right then the complaints will grow.

Has the air transport business come to the point, then, where there is not only the need to make a practical, thorough-going re-appraisal of the necessity of "standardization," but also where this can be done in the knowledge that, on the one hand, the costs of "non-standardization" are reducing, while, on the other, slavish adherence to the international book is costing more money in unnecessarily high operating costs?

The B.L.E.U. landing techniques are now to be exploited by civil aviation. The benefits will come gradually but they are quite specific. Initially, they will bring maintenance of present landing limits with the new aircraft and ultimately automatic landings in all conditions. Here is a case where the gains to an airline operator would be amply big enough to justify him in fitting his fleet even though the absence of international acceptance, or even the risk of it, deprived him of the counterpart ground installations elsewhere than at his home airfields. The costs of cancellations and diversions are, as B.E.A. have shown, very high in the poor weather areas of the world. If they can be reduced at a small price in airborne equipment, then the way to go about it is clear. One suspects that other operators would quickly follow suit.

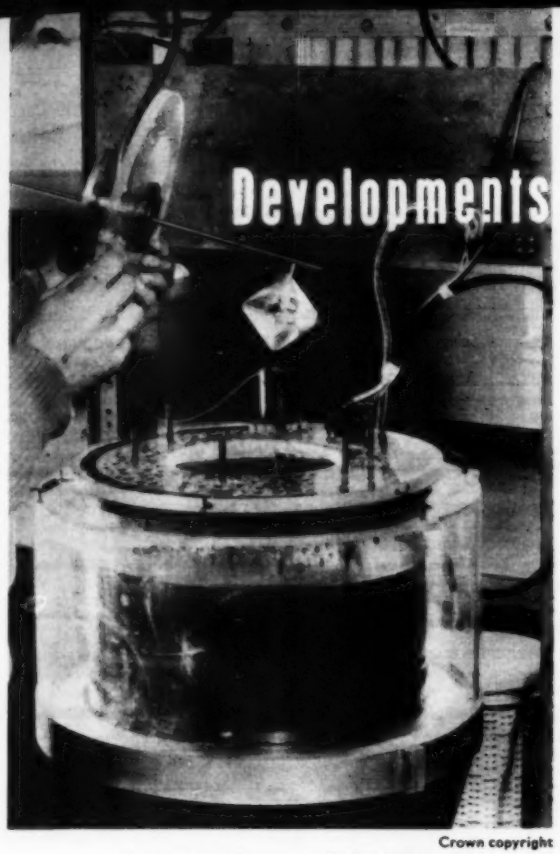
The auto-landing example is one case and probably the one most amenable to economic measurement. Yet another, of similar economic importance though perhaps not so readily measured, is that of climb-out and descent of the big jet. Enforced departures from the desired vertical profile are costly and an accurately defined flight path with freedom of horizontal choice is needed. This is in fact the Decca Navigator case and a new airway has been created by M.T.C.A. for the purpose of profiting from it.

The first thing to be said about what would certainly be a novel approach to standardization is that it introduces a note of anarchy which could easily get out of hand if many countries went off on their own private solutions. But this danger exists more in theory than in fact because not many countries have such a deep commitment in electronics or air transport development. The second point, which must be stressed again, is that the air carrier industry cannot afford to be deprived of the fruits of modern progress in the electronics art and will, more and more, have to measure in explicit terms the cost of not doing something which is technically feasible. The third point, perhaps intrinsically the most important of all, is that the spectacular reductions in equipment weight pave the way for a much more empirical approach to standardization. To put it differently, there can now be much more trial and test before a new step is exposed to the rigours of the conference table.

This, then, is one way of making progress against the impediments which are now endemic to the international family. By itself it is a highly practical measure of national self-help made possible by scientific advance. The more fruitful the results of this sort of attack are seen to be, the stronger will it become as an influence in international policy-making. It would be a hundred-fold better if the U.S. themselves would modify the constrictions of their national policy machine and permit external factors to influence its decisions. For the U.S. to end her isolationism in the aviation technical field would be a major heart-searching comparable with an earlier one in her history. But the radio-technical art is capable of devising solutions as acceptable to the private owner with a slim pocket but a nice aircraft in the western plains as to the airline operator carrying his commercial load into Amsterdam, Bangkok or Calcutta. The Pyrrhic quality of the victory in Montreal, which standardized Vortac in circumstances least likely to promote confidence that it is the right solution, will not pass without its mark in the U.S. To open the doors on policy-making is to surrender a measure of national sovereignty, and it will not take place overnight. It is rather a case of encouraging new attitudes to an international problem—a readiness to solve national problems within the framework of internationally acceptable solutions. It is highly probable that the sacrifices which the U.S. would be called upon to make would be relatively small; the very size of both her aviation and electronics industries would be the best assurances she could have. But the advantages to be gained by the restoration of authority to the international body and by the resulting confidence in the decisions made would amply reward the step.

If it is conceivable that some such development as this may come about, the fact that it could have little effect on what is going to happen in facilities standardization over the next several years is no disqualification to its desirability. The next few years will be part compromise, part acknowledgement that there are ways which lie apart for the time being. But a start would be made if there was an agreement that the transition from the national to the international way of life was desirable.

If there is latent in the present situation any possibility at all of this coming about the U.K. will need to look to its resources. Above all it will need the strongest possible Government leadership. Without this, there can be no point in liberalizing the present policy-making processes. It will need also a strong unity of purpose to be shared by Government and industry—a technical partnership of a kind which seems the fortunate distinguishing feature of the newer technological industries in this country, but not yet of the civil air transport business. Equally important, it will reveal a need for industry itself to find ways and means of integrating the individual strengths of its components; to turn its many and varied development capabilities into what Britain does not truly have at present, that is, an aviation electronics industry. Given these things, British industry would be able to make its contributions in this field as great as those it makes in fields not so far dominated by the international veto.



Crown copyright

A maser crystal grown at R.R.E., Malvern

Developments in Aviation Electronics

By G. D. SPEAKE, M.A.*

THE science of aeronautics is now so intimately bound up with electronics that there can be few electronic developments which are not destined to be applied at some stage in the aviation industry. In addition, the advance of the industry itself creates a continual demand for electronic accessories and acts as a spur to development. In most instances, however, the time scale from conception of the idea in the research laboratory to practical application in production equipment remains long.

It is in fact true to say that, in general, the time required for a development of a new electronic component to the state of full operational usage is of the same order as that for a major mechanical unit. For example, the idea for a travelling wave electronic amplifier was conceived by Kompfner in 1944, and within a short time it was demonstrated that a valve embodying these principles could be constructed. But it was about ten years before the full potential of the device as a power amplifier for broadband communications links and as a low noise receiver was realized and it was put to significant operational use. Similarly, the transistor was announced in the Bell Telephone Laboratories in 1949 but, in spite of intensive research in America, the United Kingdom and many other countries, nearly ten years elapsed before transistors began to become everyday accessories.

These time scales are very comparable with those required for the development of a major mechanical component, such as the turbojet engine, or a new aircraft. It is perhaps pertinent to ask why development should be so protracted, especially since the achievement of a working device in the laboratory often requires a year or less and some devices, such as the klystron and the high power magnetron, were even brought into service under war-time conditions in a very much shorter time. The answer to this problem is complex, but to a large extent it lies in the requirement for reliability, a quality which was sacrificed in wartime in the interests of speed but which is imperative in normal circumstances, when servicing staffs and costs must be kept as low as possible. The requirement is perhaps more important for airborne equipment than for any other because not only is the safety of the passengers and crews at stake, but also constriction of space and the desirability for rapid turn-round of aircraft make frequent servicing a difficult and costly operation.

The train of communication of information, which is perhaps the most important of the many applications of electronics in the aeronautical industry, is from transmitter through aerial and propagation path to the receiver and thence to data-processing equipment, by means of which the information is stored and presented in the required form. Some recent developments which have potential application to each stage of this process are described here, and the special requirements of airborne equipment considered.

Transmitting Elements. During recent years, developments in transmitters have been more in the nature of improvements to existing techniques than of fundamentally new processes. For example, for airfield-based and airways surveillance radars, magnetrons with increased power outputs and klystrons for broadband, high-power operation have been produced and are being put into service. Of these two types of high-power generator, the magnetron is a self-oscillator, but the klystron may be used as an amplifier and may therefore be driven from a constant frequency reference source such as a quartz crystal. This is useful in radar systems incorporating M.T.I. or clutter cancellation facilities where a highly stable reference oscillator, with a constant frequency relationship to the transmitter, is necessary. An example of a high-power (600 kW) radar with M.T.I. facilities and using a klystron is the Marconi S.264A using the English Electric K347 klystron. This has been brought into service during the past year, and is basically a development from an earlier equipment with similar M.T.I. characteristics but shorter range capabilities. It is interesting to note that developments on equipments of this type began very soon after World War 2, using principles established during hostilities.

The use of higher transmitter powers results, of course, in an increase in operational range, but it must be appreciated that the increase is obtained at some cost. Transmitting valves tend to become large, especially at the lower radar frequencies—the 600 Mc/s klystron is about 5ft long. High-voltage power supplies and relatively expensive modulating valves are needed. There is also an increased risk of injury to operating personnel both from the increased radio frequency power and from X-rays resulting from the high voltages used, so that additional safety measures must be built into the equipment. If, therefore, the increased range may be obtained by improvements to receiver sensitivity, instead of increase in transmitter power, the cost will be reduced.

The development of M.T.I. systems has been of great importance in airfield radar, since local clutter can impose very serious limitations on operational cover at short ranges (up to say 20 miles). A recent advance which was inspired by the need for good M.T.I. systems was the development of the ultrasonic delay line made from fused quartz. The M.T.I. system requires an element which can be used for providing a fixed delay between pulses, of something between about 1 millisecond and 4 milliseconds depending on the equipment. Such an element can conveniently consist of a transducer in which the radio frequency pulse of, say, 20 Mc/s frequency is converted into an ultrasonic pulse by means of a quartz crystal transducer in contact with either a liquid or solid medium. At the other end of the ultrasonic medium is another quartz crystal transducer in which the energy is reconverted, so that a delayed radio-frequency pulse emerges, the delay being dependent on the path length in the ultrasonic medium.

Early M.T.I. equipments used a liquid such as water or mercury as the ultrasonic medium. This is satisfactory for a ground-based equipment but, especially as the volume and weight of fluid is considerable, could not be recommended for airborne equipment. The development of fused quartz as the ultrasonic medium, begun in America, has therefore been continued in this country, and lines with delays up to 2 milliseconds are being produced in the Marconi laboratories. They are much smaller than equivalent lines in water or mercury, and are able to transmit information over a wider band of ultrasonic frequencies. Such lines are likely to find application in airborne equipment, on the grounds of size and weight, although they are more costly than liquid lines. The cost of the line does not in any case represent a major proportion of the cost of the M.T.I. equipment.

Aerials. There are a number of clear objectives for the aerial development engineer in connection with modern high speed aircraft, and these have formed the basis on which most of the work during the past decade has been founded. In the first place the modern aircraft flies at very high speeds and the aerial must be designed with a proper appreciation of its aerodynamic implications. Much development effort has therefore been expended on the design of suppressed aerials, and on the use of the airframe itself as a radiator. The work is usually associated with a specific aircraft since the distribution of radiated power from the aerial is dependent on its position in the airframe, and is affected by any obstructions or discontinuities near to it.

The aircraft will also need to communicate with equal

(*Marconi's Wireless Telegraph Co. Ltd.*)

AVIATION ELECTRONICS . . .

efficiency in all directions, and many types of aerial designed to radiate in a uniform manner have been, and still are being, studied. The third main requirement is that the aerial shall accept signals over a wide band of frequencies. The amount of information which has to be passed from ground to air is continually increasing, and it is not difficult to visualize a stage of development at which a picture of the traffic in the vicinity of an aircraft might be transmitted to it, perhaps using digital techniques, and displayed for the pilot's benefit. There is also a need to change frequency when required in order to ensure continuous, uninterrupted communications and all these requirements add up to a demand for operation of the aerial over a wide frequency band.

Among the types studied during recent years are dielectric aerials in which the radiator is a suitably shaped piece of low-loss dielectric material, logarithmic aerials which consist of a number of radiating elements graded in length and spatial distribution so as to cover a wide frequency band, and slot aerials which are a part of the aircraft surface. All of these will find application in the coming years, but it remains true to say that, until aircraft are a good deal more symmetrical in form the aerial will, in most cases, have to be tailored to the particular aircraft.

Among developments of particular interest to the aerial designer has been that of the class of materials known as ferrites. These are non-conducting materials with controllable magnetic properties, and are made by powder metallurgy techniques. For example, the magnetic permeability of a ferrite may be changed by application of a magnetic field to it. Thus if a slab of ferrite is placed in a waveguide, the velocity of the electromagnetic wave in the guide which is dependent on the permeability of the medium, can be controlled by application of a magnetic field. This is the basis of the ferrite phase shifter. Ferrites may also be used as non-reciprocal elements or isolators, i.e., devices through which energy can be transmitted in one direction but not in the other. Isolators can prevent energy reflected at an aerial instead of being radiated, from re-entering the transmitter. Such components are increasingly coming into use in both ground and aircraft waveguide systems. They have the disadvantage that they require a magnetic field, but this can be achieved by means of a permanent magnet and the whole package is not inordinately large. Ferrites also have uses in data processing and in parametric amplification.

Receivers. The sensitivity of a receiver, either for communications or radar purposes, is determined by the amount of noise which it adds to the signal channel because, in general, it can do nothing to reduce the noise generated externally and communicated to it by the aerial. For this reason the research and development laboratories of the electronics industry have in recent years devoted much effort both to the improvement of existing amplifiers, and to the search for alternative means of low-noise amplification.

In the first instance technological improvements to the triode as an amplifier have upgraded its noise performance considerably; for example, the Mullard EC56 has a noise figure of about 5.7 dB at 600 Mc/s, which represents an improvement of about 4 dB over valves commonly used in the previous generation of radars. Similarly the General Electric (America) triode GL7077 has a quoted noise figure of 7½ dB at frequencies as high as 1,000 Mc/s. Moreover, at microwave frequencies the noise figure of the silicon crystal diode has been brought down to something between 7 and 10 dB, which represents a considerable improvement on that achievable a decade ago. These are technological improvements which have resulted in very significant increases in receiver sensitivity but do not constitute a fundamental advance. The development of the travelling-wave tube did, however, represent a fundamental breakthrough in low-noise amplification.

The thermionic valve has an unfavourable feature from the point of view of noise generation in that it contains a hot cathode, and since the noise component in the current through the valve is proportional to temperature there would be a distinct advantage if the valve could be operated without the high temperature element. But this measure is not practicable and it must be accepted that noise originates at the cathode in all thermionic amplifiers. Methods of reducing the noise in beam-type tubes, notably the travelling-wave tube, have been discovered, particularly in theoretical and practical work carried out by workers at R.C.A. in America during the early 1950s.

A schematic diagram of one form of a travelling-wave tube is shown in Fig. 1. An electron beam originating at the cathode C passes through the helix H and is collected by the collector D. The electrons are confined to a beam by a longitudinal magnetic field not shown in the diagram. A radio frequency signal is coupled by some convenient means on to the helix at A, and provided that the beam velocity and the helix pitch and diameter are in the correct relationship to each other there will be a continuous reaction between the electron beam and the travelling electromagnet wave on the helix, as a result of which an amplified signal can be coupled from the helix at B. It will be apparent that if there are radio frequency components of electron current at A, i.e., noise on the beam, they will also give rise to signals on the helix which will show as noise at the output B. The improvement resulted from an appreciation of the fact that by insertion of suitably disposed electrodes with correctly applied voltages the noise fluctuations originating at C could be made to diminish to a minimum at A. Unfortunately, it was not possible to remove the noise completely because there are two sources at the cathode, the random variation in the number of electrons emitted per second and the random fluctuation in electron velocity, and they are not coherent. Nevertheless noise figures better than 7 dB have been obtained from production travelling-wave tubes, e.g., the R.C.A. 6861, at frequencies as high as 3,000 Mc/s; and similar performance figures have been achieved in numerous other tubes made in U.S.A., the United Kingdom and a number of other countries. As stated earlier the travelling-wave tube was conceived and demonstrated in 1944 and the theory of noise reduction was outlined in the early 1950s. Travelling-wave tubes have in fact been in practical use as broadband amplifiers for radio links in this country since 1952, and low-noise tubes are coming into limited use for both radar and communications. They lead up to the more recent electron beam-type parametric amplifier.

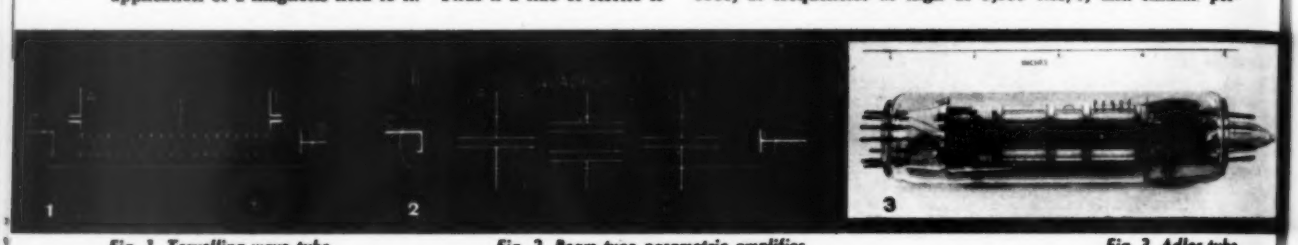


Fig. 1. Travelling-wave tube *Fig. 2. Beam-type parametric amplifier* *Fig. 3. Adler tube*

This tube was first described by Adler of the Zenith Corporation in America in 1958. A schematic diagram of such a tube is shown in Fig. 2 and a photograph in Fig. 3. As in the travelling-wave tube an electron beam travels from a cathode C to a collector D under the influence of a confining magnetic field. The magnetic field is, however, adjusted so that the "cyclotron frequency," i.e., the natural frequency of revolution of the electrons in the magnetic field, is equal to the radio frequency which it is desired to amplify. The signal to be amplified is applied to a coupler A, which consists of a pair of plates that impose a transverse electric field on the beam. In these circumstances a spiral motion is imparted to the electrons, the diameter of the spiral increasing as they pass through the coupler. In the absence of any other disturbing influences the energy which the electrons have so acquired is given up in a second, identical coupler B to a matched load which is, in fact, the input to the next stage of the amplifier. If, however, an electric field rotating at twice the frequency of the r.f. signal is applied to the beam between A and B, the diameter of the spiral continues to increase, so that an amplified signal is obtained from B, the power for amplification having been supplied by the double frequency pump signal. In the Zenith tube the rotating field is obtained by applying radio frequency voltages to two pairs of plates arranged so as to produce electric fields at right angles and in phase quadrature. The arrangement is called a quadrupole.

In practice, the conditions for amplification when the pump frequency is exactly twice the signal frequency are critical, but it may be shown that stable amplification is achieved when the frequencies do not bear a precise 2:1 relationship. It will be seen that the transverse coupler has been used both to couple signal on to the beam and to extract it again. Thus it can be appreciated that the input coupler A will react with noise signals originating at the cathode and present on the beam when it reaches A, and that providing that the signal source presents a good match the noise signals can be removed in it. In a practical tube the transverse signal fluctuations in the beam are reduced

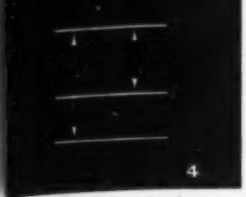


Fig. 4. Energy levels in a molecule

to a minimum by suitable design of the electron gun, so that the process of noise removal at the input coupler A is not made unnecessarily difficult, and noise figures less than 2 dB at frequencies around 600 Mc/s have been reported. The tube as described is suitable for use at frequencies up to 800 Mc/s or so, and with appropriate modification is likely to be extended to microwave frequencies.

As indicated earlier, this type of amplifier is about two years old. Development work is proceeding and its properties are being studied in many laboratories. It is a multi-electrode device and as such its production cost may be perhaps twice that of the low-noise triode, but it may well prove to have a longer life and it should be less susceptible to damage by high-level radio-frequency signals, such as are received from the transmitter in radar applications. Moreover the financial cost of an improvement in performance of a communications or radar system is less if it can be achieved at the receiving rather than the transmitting end, since the required power supplies are less costly. For this reason the electron beam parametric amplifier may well go into service in airfield radars and possibly even in airborne equipment, since its size is not prohibitive, during the 1960s. There is, however, still much to be learned about the operation of tubes of this type and they will have to compete against another class of parametric amplifier based on semi-conductor elements.

In 1957 Bloom and Chang outlined in the R.C.A. review a theory of amplification using non-linear reactances, a concept which was by no means new, having been discussed by Lord Rayleigh in the 1880s. But the advances in 1957 and since have resulted from improvements in the technology of semi-conductor development whereby components suitable for use at microwave frequencies have been manufactured. In essence the solid state parametric amplifier consists of two coupled circuits resonant to frequencies f_1 and f_2 respectively, and incorporates a reactive element the magnitude of which can be varied. If the reactance is varied at a "pump" frequency (f_1+f_2) it can be shown that amplification can be obtained at either frequency f_1 or f_2, i.e., the power necessary to amplify at f_1 or f_2 is obtained from the "pump" which operates at f_1+f_2.

There are two possible forms of solid state element which can be used as the variable reactance element, the ferrite and the semi-conductor diode. The ferrite is used as the basis of a time varying inductance and the semi-conductor diode as a time varying capacitance. Other materials will no doubt be proposed as time progresses but, at the present stage of the art, the semi-conductor diode appears to offer most promise, especially since the pump powers required are very much lower than for the ferrite and, additionally, no magnetic field is necessary. In the two years or so since the use of these elements was first proposed, practical amplifiers have been made at a number of frequencies in the microwave band, and the solid-state parametric amplifier is already well established. Amplifiers of this type contain no hot cathode or other element at temperatures higher than that of the environment in which the diode is contained. The noise generated within the diode is therefore low, and amplifiers with noise figures as low as 1½ dB are in production in the U.S.A.

The success of such amplifiers is in a large measure dependent on the precision manufacture of the semi-conductor diode. Considerable advances have already been made in this direction and diodes suitable for use in amplifiers operating at frequencies well above 1,000 Mc/s have been made in the U.S.A. In this country the diodes readily available are suitable only for frequencies up to a few hundred Mc/s, but substantial improvements may be expected and within the next few years it can be predicted that parametric amplifiers will be in extensive use in aviation for communication, telemetry and radar purposes. Of all the available low-noise amplifiers they are the most attractive for airborne use since they demand no magnetic field, operate from low D.C. voltages and, although they do require a radio frequency source for the pump, the power delivered by it needs to be only a few milliwatts. The diode is also a robust unit, able to withstand considerable vibration, but it is necessary to impose a limit on the ambient temperatures in which it is required to operate.

A final class of amplifier of potential use to the industry is based on the MASER (microwave amplification by stimulated emission of radiation) principle. The discovery of this phenomenon emerged from a study of the resonant states of molecules, and its potential as a low-noise amplifier was soon realized. In essence a maser depends on the fact that transitions between two quantum energy levels in a molecule may be induced by radiation at a particular frequency, and that when such a transition takes place energy at the same frequency is emitted. Thus energy at a particular frequency is supplemented by internal energy from the molecule, i.e., amplification takes place.

It should be emphasized that in the equilibrium condition the molecule does not have excess internal energy, the more usual process being absorption rather than emission, but that in certain circumstances it can be raised to a higher energy state, for example by thermal means or by means of an applied signal from a source called a pump. For example, in Fig. 4 the three lines represent energy levels of a molecule, and transitions from level 1 to level 3 may be inducd by application of energy at a frequency f_{13}. The molecule is then unstable and may revert to its original state by emission of frequency f_{13}. However, the transition from level 3 to level 2 may also be possible and can in fact be stimulated by application of a signal of frequency f_{23}, i.e., amplification is obtained at frequency f_{23} by pumping at frequency f_{13}.

The first application of the maser was reported by Gordon, Zeiger and Townes of Columbia University in 1954. They made an amplifier in which transitions between energy states in the ammonia molecule were used as a basis of amplification. Some of the molecules were excited to a higher energy state thermally and the system was designed so that only these molecules were effective in the amplification process. The energy states are fundamental to the molecule and invariant so that, just as with the cadmium line in optics, the amplifier could be made a source of standard frequency. In fact, the necessary feed-back loop was incorporated so that the amplifier became an oscillator of standard frequency (23,870 Mc/s), or more colloquially the ammonia clock.

A similar frequency standard has since been built at S.R.D.E., Christchurch. A "cesium clock" based on similar principles, but using transitions between energy levels in the cesium atom has been in operation at the National Physical Laboratory for about two years. Both these clocks are capable of an accuracy an order of magnitude greater than those of the previously accepted standards based on quartz oscillators, and it is probable that they will be applied in ground-based equipment during the next few years.

There is, however, another type of maser of potentially greater interest. In this, the molecular energy levels are conditioned by the application of a magnetic field. Thus the frequency at which amplification is obtained is no longer invariant, but can be changed by variation of the magnetic field, and the device becomes of practical use as a microwave amplifier. Much experimental work on this form of maser has been carried out, particularly at Bell Telephone Laboratories and M.I.T. in America since 1957. It has one serious limitation. In general, most efficient operation can only be achieved by cooling the magnetic material to liquid helium temperatures. Liquid helium is indeed readily obtainable from the National Physical Laboratory and, as time progresses, relatively cheap and portable helium liquefiers will become available, but the handling of the liquefied gas and the provision of the necessary low-temperature apparatus impose restrictions which are likely to be unacceptable except for large, ground-based installations.

The big advantage of the maser is that, since again it contains no high-temperature elements and in fact operates at temperatures near absolute zero, it introduces very little noise and may therefore be used as a very sensitive amplifier. Its main application in the near future is likely to be in radio astronomy where its relatively large size and the inconvenience of handling liquid helium may be acceptable. A maser has in fact already been used in association with a radio telescope at Harvard University. But the Radar Research Establishment at Malvern has operated a maser at the much more easily achieved temperature of liquid nitrogen although with some reduction in noise performance, and it is possible that within the next five years a practical amplifier for ground-based radar applications will emerge. The maser is most likely to be of use at frequencies above, say, 5,000 Mc/s where the parametric amplifier is more difficult to manufacture.

The Atomichron cesium clock produced by the National Co. Inc. during 1956. A similar device is operating in the National Physical Laboratory

Data Processing. The developments considered so far have

been concerned with the gathering of information. In fact the amount of information assembled, for example, in the control room of a busy airfield may be embarrassingly large, and unless it can be stored and presented to a controller in a manner which he can readily absorb, much of it may be wasted. It may, moreover, be necessary to pass much of this information over radio links to the pilots of aircraft in the vicinity, and it must therefore be converted into digital or some other convenient form for transmission, channelled into the links and re-processed for presentation in the aircraft. It can be envisaged that, as air traffic increases, this presentation might take the form of a pictorial display in the aircraft of the operational situation in its vicinity, so that the pilot could take his own measures to ensure the safety of his passengers and crew. With these requirements in mind it is not surprising that in recent years considerable research and development work in the electronics industry has been devoted to digitizing, storing and channelling of information.

Bright Displays. Radar information has the distinct advantage that it is conveniently displayed on a cathode-ray tube, a manner of presentation which the human operator readily accepts. There are, however, disadvantages in the usual cathode-ray tube in that it is not a bright form of display, so that it must be viewed in subdued light, and it does not store information. Limited storage facilities are obtained by using tubes with long-afterglow screens, but this can prove to be an embarrassment since the stored plots cannot be erased at will. Many types of electron tube designed for storage of information have been studied during the past decade but relatively few have had significant operational use. In most of them the primary information is stored in the form of a controlled distribution of electric charge on a mosaic, and is "read" off by a scanning electron beam. One of the more successful tubes of this type is the C.S.F. TI.440, manufactured in France, which has been available for the past two years or so. Storage tubes are, however, complex and involve very specialized manufacturing techniques and further development work is required to improve the definition obtainable from them. It is therefore doubtful if they will come into large-scale use for some years to come.

Information which is not readily displayed by cathode-ray tubes, or which has to be transmitted over a data link, may well be coded into digital form and will again require to be stored. The storage of information on magnetic tape or drum is now well established, and the use of minute ferrite elements as magnetic stores has also become commonplace in recent years. During the last two years, however, a new component for the storage of digital information has become available and it deserves mention because of its ability to operate at very high speeds and because it is an example of the application of a phenomenon, discovered many years ago in the realm of experimental physics, to the solution of a practical problem.

In the storage element use is made of the phenomenon of superconductivity. A superconductor is a material whose electrical resistance suddenly vanishes when it is cooled below a critical temperature, near absolute zero. The superconductivity may, however, be destroyed by application of a magnetic field. For example, if a tantalum wire is threaded through a solenoid and cooled to below 4 deg K, it will normally act as a nearly perfect short circuit, but when current is passed through the solenoid so that the wire is in a magnetic field a finite resistance is restored. It will be appreciated that this may be made the basis of a switch, with the qualification that in neither position is the switch truly "open" because operation is achieved by application or removal of the magnetic field. This device is known as the cryotron and was first described by Buck of Lincoln Laboratories in America in 1956. It may be used not only for switching but for storage of information and is therefore applicable to high-speed computing. Switching times as short as 10 microseconds have been reported by the General Electric Co. in America, and developments can be envisaged which will permit even higher operating speeds. Since superconducting elements have zero resistance, currents can be kept circulating in them for very long periods (e.g., several years) and this property is used in another computing element reported in America in 1957 and known as the Persistatron. The practical limitation on the use of such elements lies, as in the case of the maser, in the need for apparatus for cooling to temperatures near absolute zero. On these grounds it is difficult to visualize airborne applications for some considerable time to come. With the development of commercial helium liquefiers, however, the superconductivity store may well be applied in traffic control centres.

Miniaturization. There has been a steady trend towards smaller components in electronics since the end of World War 2. The reasons for this, particularly in airborne equipment, are obvious. A good deal of equipment of all types has to be packed into the modern aircraft and in positions where it does not interfere with operation. Moreover, as already emphasized, with the steadily increasing density of air traffic demands will arise for the transmission of more information from ground to air and vice versa, and the electronic equipment may be expected to increase in volume and complexity. The necessity for condensing it in size and for sub-dividing it into readily replaceable units for easy servicing is therefore obvious.

There have been considerable technological advances in the miniaturization of electronic valves, especially during the early 1950s, and compact amplifiers using miniature wired-in valves, with heat dissipation several times less than was previously achievable are now commonplace. This form of improvement should not be forgotten when considering the more fundamental changes which have resulted from the development of devices such as the transistor. Another major advance has been the widespread use of printed circuits. As any enthusiast who has removed the back from his radio receiver will know, the wiring of even the most straightforward electronic circuit is complex, and the possibility of error during manufacture and of contact between neighbouring conductors caused by vibration, heating or other effects in service must be carefully guarded against. In the printed circuit many of the problems are removed since the wiring, and indeed some of the circuit components such as coils, may be produced by etching from a dielectric-backed copper sheet. The pattern is reproduced photographically and manufacture becomes not only cheaper but less subject to human error. Moreover, the wiring is now virtually two-dimensional and the depth of units is much reduced.

Printed circuits are now becoming commonplace in the industry and are resulting in greater reliability and toughness and better utilization of space. It may be mentioned in passing that similar techniques are likely to be used in the future for manufacture of feeder lines to aircraft aerials, and perhaps of the aerials themselves. Because they will be in flat strip form they may be designed to fit flush to the surface of the aircraft.

Micro-miniaturization. The art of compression of electronic equipment has now advanced a stage further with the advent of micro-miniaturization. This utilizes the technology of evaporation of metal and dielectric materials *in vacuo* to produce thin films on a plastic or ceramic sheet base. For example, films of metals can be used as good electrical conductors, such as would be necessary for coils or inter-component wiring, or as condenser plates, or as relatively high resistances for use as circuit elements. Similarly, thin films of magnetic material such as nickel may form the basis for magnetic storage elements. The dielectric for the condensers may be formed by the plastic base, or could be specially evaporated. These processes are in their infancy and require technological development. For instance, improvements in dielectric materials for use at relatively high temperatures and in control of the evaporation process will result in more reliable units.

Perhaps the greatest contribution to miniaturization has been the development of the transistor. It is not only very much smaller than its counterpart the electronic valve, but also runs from compact, low-voltage power supplies and dissipates very little heat. Large numbers of transistors may therefore be packed close together without introducing major cooling problems. It should, however, be mentioned that the germanium transistor in particular does not perform satisfactorily at temperatures above 70 deg C or so, and some control of ambient temperature may be necessary.

The subject of semi-conductor development has occupied research workers in many laboratories throughout the world during the past ten years and the technology has advanced considerably. For example, whereas the early transistors were suitable for use only at relatively low radio frequencies, development of the process of diffusion has allowed transistors to be manufactured which are suitable for use as amplifiers at frequencies as high as 1,000 Mc/s. The use of silicon as a semi-conductor element has also extended the upper limit of working temperature, albeit at some cost because the metallurgy of silicon is very difficult. One of the most profitable uses of transistors is in the digitalization of information, which requires the use of large numbers of switching elements. In this connection it is of interest to note that the speed of the transistor may be about 1,000 times that of the cold-cathode gas-discharge switch.

The use of transistors, together with miniaturization and micro-miniaturization techniques has resulted in very compact and tough units. It has also demanded a change in servicing philosophy. It is now necessary to replace not only the valve, condenser or other faulty element in an unserviceable unit, but the whole unit itself. The relative cost of this, which at first sight would appear to be high, does not turn out to be so in practice, because the high cost of locating and replacing a faulty component, especially in the airborne environment, and also because the encapsulated, transistorized component is a reliable long-life unit.

There are of necessity many developments in electronics not covered by this review and many other applications of electronics exist, for example in servo-control mechanisms and in control of machine tools for aircraft manufacture. It is clear that the impact of the current developments in electronics will be as great in the aircraft industry as in almost any other.

An Airline's Attitude to New Electronic Equipment

By D. O'HANLON*

AIRBORNE communications and navigation facilities are required in order to ensure the safe operation of the aircraft in all conditions. Owing to the high rate of expansion of air traffic in the past ten years the need for more complex systems placed heavy demands on the skill of equipment designers if the payload were not to be severely affected. In the airline view, safety and reliability come first but as payload is our bread and butter any development which can reduce weight has a high priority.

Weight cannot be "saved," it can only be afforded. If it is reduced unduly, the serviceability of the system is bound to suffer. The designer of equipment must use his judgment, with the guidance of the customer, in striking the balance. In general, the development of equipment has been related to circuit techniques. An outstanding case is in V.H.F. communications equipment. A typical four-channel unit of the late forties has a transmitter output power of 3.5 W and a receiver sensitivity of 10 microvolts for standard output. The primary input power was 180 W and the weight of the main units 22 lb. Typical equipment now available has the following comparable figures: 360 channels, a transmitter output power of 25 W and a receiver sensitivity of 3 microvolts for standard output. Input power is 290 W and the weight 36 lb.

Two main developments have been responsible for these improved figures, crystal-saving techniques in the frequency generation circuits and the introduction, although only in a limited way, of the transistor. There were five crystals in the early four-channel set, and there are only 39 in the 360-channel set. The crystal-saving techniques in the latter set make use of the arithmetic of the frequency multiplying circuits and the relationship between the frequencies required by the transmitting and receiving functions. All the circuits in V.H.F. equipment cannot yet use transistors. They have been used mainly in the receiver at the intermediate radio frequencies and also for audio purposes and speech modulators, but the numbers employed have reduced size, weight and power requirements.

The use of transistors in airborne equipment poses some special problems apart from those associated with their use as electronic circuit elements, notably variations in ambient temperature, and the characteristics of the aircraft electrical power supply. Nevertheless, all the evidence goes to show that the transistor will be established as a major development achievement for airborne application. A fully transistorized cabin address equipment has already been developed which for the same weight and size will supply twice the number of loudspeakers as its predecessor. This is an important advantage in view of the larger passenger cabins in the newer aircraft. Similarly, although not entirely due to transistors, a weather radar approximately half the weight of the previous model is now going into production.

Information on the nature of transients in aircraft power supplies is sparse. They are caused by changes in loading with the intermittent use of aircraft electrical equipment. The surge appears at the power input terminals of the radio equipment and, if of sufficient amplitude and duration, can cause breakdown of the transistors. We are at present engaged in an examination of the problem with specially designed transient recorders, and have protected transistor equipment with transient "blankers."

Weight being an extremely important factor in aircraft economics, miniaturizing has become most important in offsetting the rise in weight caused by increasing operational needs. But weight-saving must not be achieved at the expense of safety or reliability. There are cases where serviceability has been materially reduced because components have been made too small or too light, particularly mechanically or electro-mechanically. The limiting item on our scheduled overhaul period at this time is the rotary transformer where, in order to provide a satisfactory output at a low weight, the machine is run at a very high speed causing a high rate of failure of armatures, brushes and bearings. The small weight-saving has certainly not been worthwhile. Fortunately the transistor may be helpful in this case, too, because it is now possible to replace these devices by a non-rotating power converter, and its use in airborne equipment is now being examined. Developments are not all profit. Every advantage always has a corresponding disadvantage, and we must sometimes settle for only marginal gains. For instance, the all-up weight of radio equipment on the early post-war aircraft was about 600 lb, and that on the aircraft now being delivered has risen to about 1,800 lb in spite of quite considerable weight-savings on some systems. If the weight had been scaled up in proportion to the additional facilities provided, it might easily have been two tons.

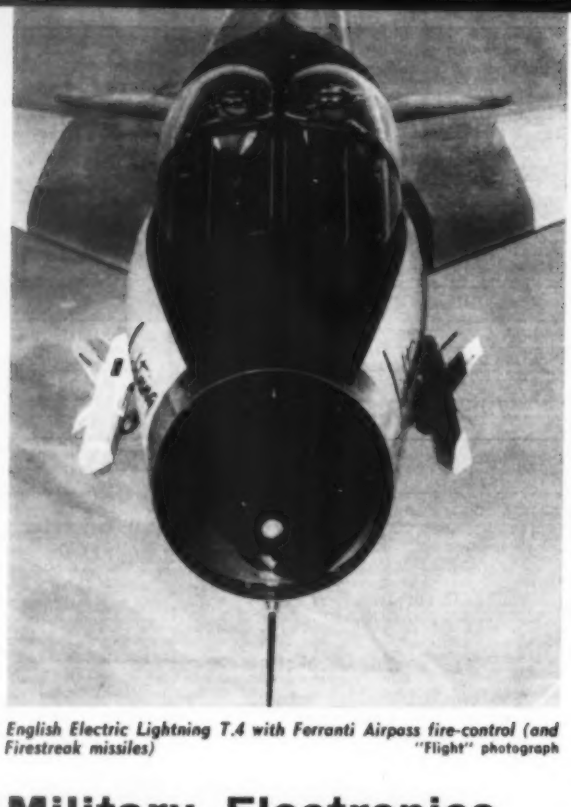
In general, an airline operator is only able to take advantage of major advances in electronic techniques when ordering a new aircraft, or when carrying out a major modification programme to an existing fleet where the introduction of a new system is required. There are cases, of course, where as a result of investigation into recurring defects such as the rotary transformers mentioned, it becomes possible to consider the case for a major change to incorporate an entirely new development such as the transistor power unit. The final decision will depend on a satisfactory presentation of the economic balance sheet in the form of a modification proposal showing the advantages to be gained against existing costs. The effect of a change of weight by the modification is assessed by the use of an arbitrary figure for the revenue cost per pound of payload on a "fleet life" basis to ensure that uncontrolled weight increases do not occur.

There are several factors to be taken into account when considering the effect of new developments on aircraft equipment programmes, not the least of which is the airline maintenance method. It is quite certain that the introduction of transistorized equipment calls for the employment of entirely different servicing techniques, and a considerable training programme is needed.

Before deciding to introduce such major changes, a complete evaluation of the proposal is made. Firstly, the new system is examined and a specification written, taking into account the performance needed to meet mandatory requirements during the period between equipment overhauls. In discussing these requirements with designers, there is nearly always a background of development experience on the system specification and the emphasis is therefore on the application of those techniques which represent the developing state of the art. It is sometimes necessary to exercise control over those items with a known history of unreliability, but the designer otherwise has complete freedom to use his ingenuity to produce an equipment which will do more, and do it better than before. How well the equipment meets the overall requirement is judged by the evaluation of models in the Radio Laboratory where measurements of performance and an assessment of maintainability are carried out.

To summarize, airlines are operating in an area of constantly developing technical progress, but with the rate at which the need for electronic facilities is growing we can only remain economic if this is offset by the application of techniques which will reduce weight and increase reliability. The introduction of transistors may help towards this end, but this has still to be proven during the next few years. Beyond that, dramatic gains from "solid circuits" may come—but that is another story.

*(*Radio superintendent, project and development, B.E.A.*)



English Electric Lightning T.4 with Ferranti Airpass fire-control (and Firestreak missiles) "Flight" photograph

Military Electronics

By K. E. HARRIS, B.Sc., M.I.E.E., M.Brit.I.R.E., S.M.I.R.E.*

ELECTRONICS for military aviation is in its precocious infancy. In its own youthful opinion there is nothing it cannot do and its supporters sometimes claim that the aircraft is secondary and only the electronics count. But in all modesty, the achievements are considerable and now, fifteen years after the war which gave aviation electronics its great impetus, may be a convenient moment to survey progress. The electronics engineer certainly faces the problem of choosing the right applications for his art in an era where the possibilities are manifold and the design effort is limited. He is also clearly in a position of great responsibility to military aviation, as can be seen from the fact that a third of the cost of an armed V-bomber is accounted for by electronic equipment.

Naturally, a review of this kind must be incomplete. Discussion of most recent equipment is forbidden, but observation of the ten per cent of the iceberg which is visible may give a fair idea of the nature of the mass which is submerged in the sea of security.

The history of the application of electronics to military aviation can be divided into four phases. First, simple attempts to communicate between aircraft and the ground; second, the early designs of navigation aids; third, the growth of specialized defence and attack systems; and fourth, the emergence and engineering of the integrated weapon. Roughly, these phases coincide with World War 1, the inter-war years, World War 2 and the post-war period. To an observer today one of the most impressive facts is the soundness of the thinking of the pioneers; very little energy was wasted, the beginnings were solidly founded on the needs of the moment to the limit of the available techniques. For example, the Lorenz system for blind approach remains the essence of the present internationally accepted I.L.S. and this in turn is the corner stone of the automatic landing system which is so evidently the first step in fully automatic flight for transport aircraft. Once systems of this kind have been proved in military service, they are often adopted for airline operations and the considerable influence, indeed the duty, of Service departments in paving the way for new civil equipment should not be forgotten. Most topical example of this is Autoland which is even now emerging as a commercial prospect after adoption by Bomber Command.

The H_2S system of World War 2 applied search radar to bombing and navigation. Since then it has led to the weather radar which is on the point of becoming mandatory in airliners, but it has also remained as a central element of blind bombing and navigation systems. The first advanced combined bombing and navigation radar was probably the K-system installed in B-47s. E.M.I. has since produced an equivalent for R.A.F. V-bombers and the trend is towards more and more compact equipment, leading now to radars such as NASARR (a monopulse equipment by N.A.A. Autonetics) which can fulfill both the bombing and interception functions in the same aircraft. Such equipment is of particular value over hostile territory where no assistance can be expected from the ground, but the interpretation of its information is clearly too complex to permit its use as an input to a computer and it may only be applied in manned aircraft.

A near approach to a truly self-contained aid is Doppler radar which also has emerged as a civil system. A large number of military Doppler navigators has been produced for both fixed- and rotating-winged aircraft of all sizes and it can be said to have become a standard method of providing dead-reckoning information of considerable accuracy. It is now perhaps finding its true place in the picture as a part of a fully integrated navigation system incorporating inertial and star-tracking devices feeding a central selective computer. Such a complex, fitted in the B-58 and, one may presume, in any attack aircraft of later date, is described on page 377.

The basic Doppler outputs are drift and groundspeed, which are extremely accurate. The addition of compass information produces track reference, but the accuracy of present standard compasses is well below that of the Doppler itself. Actually, accuracies better than one per cent of distance flown are now attained, although errors are cumulative and check-fixes become desirable for long-range flights. Doppler radar is generally arranged to drive a computer which produces co-ordinate information of direct use in making particular flights.

The most truly self-contained navigation aid at present is the inertial system which, in principle, is the simplest of the navigation devices, depending primarily on the use of gyroscopes. But it is only recently that the techniques of producing gyros of sufficiently high quality in considerable quantities have been mastered. English Electric and Ferranti in Britain, a dozen companies in the U.S.A. and undoubtedly a number of organizations in Russia are producing gyros and accelerometers of inertial quality. Computer techniques have advanced sufficiently to make it possible to provide inertial guidance for all manner of vehicles, and there is almost unlimited freedom in the degree and type of "inertiability" adopted for a particular application. Short-term, long-term, pure and hybrid have become inextricably confused, and little can be done to clarify the situation until security restrictions are further lifted.

Inertial navigation, in all its infinite permutations, has now definitely proved practicable for ships, aircraft and missiles and it is certain that advanced weapons now being planned will greatly rely on it. The technological "know-how" it has introduced is also being applied to other fields and, only recently, the Minister of Supply referred to the "industrial revolution" it had brought about in Britain. As far as is known, Sperry are working on the guidance for Blue Streak which is presumably inertial and Elliott Brothers (London) are working on the inertial guidance of the Avro stand-off bomb. English Electric are preparing to produce the Minneapolis-Honeywell miniature stable platform, which has very varied possibilities in both navigation and flight control.

At present, greater accuracy can be achieved for ICBMs by the use of command guidance. It has even been said in the U.S.A. that this will give ten times the accuracy of present inertial systems and some idea of the accuracy aimed at may perhaps be gained obliquely from a Tass report that the Soviet ICBM can impact within six miles of target after a flight of over 5,000 miles.

The basis of the command guidance system originally developed for Atlas but now applied to early Titans is a Doppler radar and a precision tracking radar. The Doppler radar consists of a transmitter and four receiving stations laid out in the form of a cross. Measurement of the Doppler shift at each of the receivers makes it possible to measure the missile's velocity in three dimensions. The precision tracking radar is a pulse radar and measures azimuth, elevation and slant range. Signals from the two radar units feed a digital computer which continuously works out the missile trajectory and compares it with the required path. Correction information and optimum fuel cut-off point is transmitted back to the missile control unit. A major disadvantage of such

B.T.H. Sting Ray target-illuminating radar for Bloodhound guidance

*(Cossor Radar and Electronics Ltd.)

a system is that only one missile can be launched at a time from each site.

In the case of the satellite, the expense of a launching, the need for high initial accuracy, and the very high accelerations involved, justify elaborate developments for initial corrections even though these can be provided only for the first few minutes of flight. Mid-course guidance is, of course, one of the major goals of present ICBM development, particularly because it allows evasive manœuvres.

During World War 2, ground targets for bombers were marked by radio beams. By reference to a left/right indicator, the pilot could approach the target along a pre-determined path. Methods were developed with intersecting beams, or by measurement of range from the originating station, of marking progress along this path. This was eventually done so accurately that pilots could be instructed when to steady their aircraft on the final run-in and exactly when to release their bombs. Because the information reached the aircraft in the form of particular radio signals, an interesting opportunity arose for radio countermeasures.

The principle of beam-riding has been extended since the war, and equipment has been developed to keep a missile automatically on track in this way without the need for a real navigation system of its own. Because of its vulnerability to countermeasures, this technique will probably find its greatest application at ranges where the power of the guidance transmission can be counted on to remain stronger than enemy jamming. The A.W.A./Sperry/G.E.C. Seaslug, the Royal Navy's ship-to-air missile, is a beam-rider; so is the corresponding American weapon (Terrier) and several air-to-air missiles. A beam-radar picks up the target and locks-on regardless of any evasive manœuvre. Seaslug is launched into the axis of the beam and the guidance equipment contains circuits which evaluate any positional error which the missile may have with respect to the centre of the tracking beam. Correcting signals from the guidance equipment are then fed to the control system to produce the appropriate fin movement to bring the missile back into the centre.

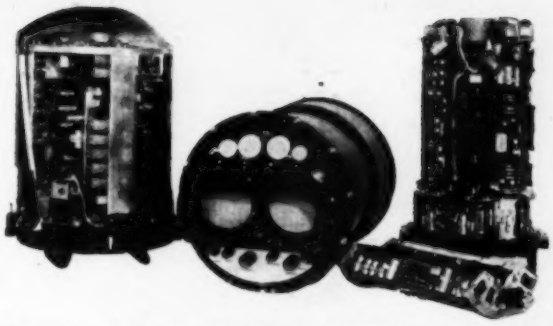
The present guidance electronics carried in the Seaslug are contained in a box 11in × 26in × 8in which gives an indication of the space necessary for equipment performing this kind of function. Some idea of the accuracy with which such a job can be done by units of these dimensions, can be gained from the fact that in six recent firings by the Royal Navy, all six targets were destroyed, and that in three other firings against jet aircraft at Woomera, two direct strikes were achieved and the third firing was intentionally programmed to miss in order to preserve the target.

In contrast, semi-active homing is employed by the Bristol/Ferranti Bloodhound ground-to-air missile, which carries a gyro-stabilized scanner in its nose. This system determines the direction of the target and the missile's computer derives information which is used to operate the control surfaces of the main wings to steer toward the target on a collision course. Radio energy received by Bloodhound is a reflection from the target of transmissions from the ground-based target-illumination radar, in this case the B.T.H. Sting Ray. The function of this radar is both to illuminate the target and to transmit signals to another receiver in the tail of the Bloodhound. Both frequency and pulse-rate of Sting Ray may be varied so that several missiles can simultaneously be fired at a number of targets—each to its own target—and jamming is made difficult.

In the early days, work was directed not only to the ground-based defence radars, but also to the provision of an offensive system to be carried in aircraft. It was first known as the "airborne instrument," or "A.I.," and these initials subsequently came to imply "Airborne Interception." Early versions operated at a frequency of 200 Mc/s and employed two pairs of dipoles and reflectors on the wings of the intercepter to determine whether the target lay to left or right. Further dipoles above and below the fuselage showed the target to be above or below. A stronger signal would be obtained, for example, at the right hand dipole when the target was off to the right, and in the upper dipole if it was above the pursuing aircraft. The relative signal strengths were presented directly on two cathode-ray tubes in front of the navigator so that he might instruct the pilot how to aim his aircraft to keep the enemy directly in front.

This process meant that the fighter had to follow a curve of pursuit, a path which is much greater in length than the optimum cut-off vector. Paradoxically, now that computers are available to calculate the cut-off vector, the disadvantages of flying the longer path are less serious than they were for the wartime fighter. The intercepter by itself, but particularly the missile, may be expected to achieve a considerable closing speed whereas, at the time of the early marks of A.I. it was questionable whether the night fighters then carrying it could even keep up with the enemy targets in straight and level flight. The aerials for the A.I. radar system itself were a substantial handicap in this respect and at least one of them became known as the "built-in headwind."

Development of the magnetron and the advance of centimetric techniques produced scanning systems using a reasonably small dish aerial which could be accommodated behind a streamlined



Components of the General Electric fire-control for the Sea Vixen

plastic nosecap. Normal pulse-radar techniques were employed with a narrow pencil beam making a helical scan. The derived information was used to put a spot on a cathode-ray tube which indicated the direction in which to look for the target.

Various steadily improving marks of A.I. were developed, all working to the operational requirement that the radar was simply required to indicate the direction of the target because a navigator was employed to direct the pilot's pursuit. A range of a few miles was thought sufficient to allow the G.C.I. operator on the ground to put the fighter in such a position that the interception could be completed by the use of the A.I. Some refinements were developed, such as the pilot's indicator which saved the time-lag caused by the navigator calling out instructions, and the addition of "wings" to the target spot on the cathode-ray tube. The wings sprouted and grew as the target drew closer. Nevertheless, at the end of World War 2, A.I. remained an indicator which required interpretation by the aircrew.

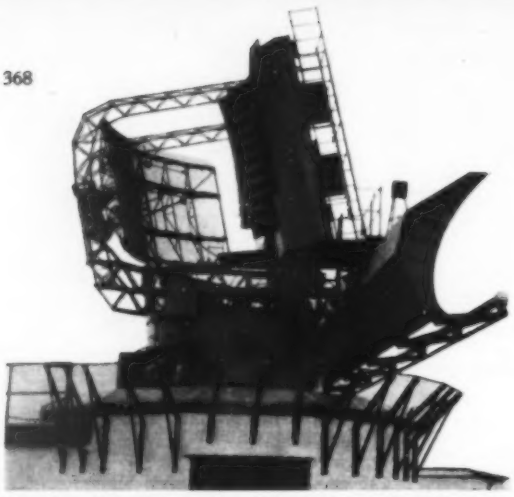
There have been substantial post-war developments. A.I. ranges were constantly improved and it became possible for the pilot to intercept and fire at a target without actually seeing it. A great advance was the addition of a computer to calculate a collision-course instead of the standard pursuit-curve approach; and this led to the adoption of spin-stabilized rockets giving a greater spread—an area the size of an American football pitch has been quoted—to the fire pattern. The rockets would be launched automatically at the right moment and indeed, the whole interception, from radar lock-on onwards, could be made under autopilot control. In the F-86D Sabre and many U.S. Navy aircraft, the all-weather intercepter became a single-seater; although this policy has never been followed in the R.A.F.—except for the Lightning F.1—and has now been abandoned by the U.S. Navy.

Finally, the loop has been almost closed by controlling the fighter directly from the ground by a data link between the control centre and the autopilot. The F-102 and F-106 both operate in this way.

Approximately parallel developments occurred in radar-laid defensive gun turrets, but these have now been abandoned by most air forces in favour of countermeasures. Defensive effectiveness of guns has never proved of a very high order, although Russian bombers have always carried such gun armament.

Most recently published British fire-control radar is the Ferranti Airpass (Airborne Interception Radar and Pilot's Attack Sight System), fitted to the Lightning. The radar is a search-and-track set and includes a computer which works out the correct course for the pilot to fly in order to position himself for the final attack. First the radar searches a wide sector of sky vertically and horizontally on either side of the flight path. When the target is located, the radar beam is locked-on to it so that it will track automatically and the computer then begins to work out the attack path. The most successful path in fact lies somewhere between the cut-off vector and the curve of pursuit. The former gets the fighter to the target in the shortest time but the curve of pursuit has the advantage that when the fighter catches up

The tactical control room, nerve centre of the modern British air-defence system. The electronic "tote" board lies beyond. Radar information is derived from the tactical radar illustrated overleaf



The Metrovick tactical radar. Volumetric scan is achieved by transmission from the aerial at right, and receiving through eleven horns after focussing by an electronic lens beyond the horn array

AVIATION ELECTRONICS . . .

with the target, they are both directly in line and on the same course. There is an optimum compromise for each particular closing speed. With Airpass, if the pilot approaches too close to his target and is in danger of colliding with it, a warning is given to him to break off the attack.

The most advanced developments are concerned with the air-to-air missile. So far as the parent aircraft is concerned, it is necessary to position it only sufficiently close for the missile to complete the interception even if the target is many thousands of feet higher up. The target may possibly be using its own defensive radar or attempting to jam its attacker and either of these transmissions may afford a guidance system to the missile. Clearly, at some loss of the information which it is itself using, the target may choose to preserve radio silence, but it is still possible for the missile to home by infra-red guidance, on the heat generated by the target. Infra-red homing heads will be sensitive to a certain range of temperatures and it is possible to alter the temperature of engine exhausts to bring it outside the critical range.

The Philco Sidewinder is a successful infra-red, direct-hit missile, but de Havilland Propellers' Firestreak, now standard in the Fleet Air Arm and Fighter Command, has a more sophisticated homing system and is also fitted with an optical system operating the proximity fuze. In Firestreak, an electronic controller works through the servo loop to minimize the rate of change of target direction; thus the missile operates to keep itself continuously aimed at the target and completes a curve of pursuit interception.

Developments in defensive ground radar cover an almost unlimited field. During World War 2, the radar designer lived from hand to mouth with his component supplies and one of the great feats of the time was to get the cavity magnetron from Boot and Randall's laboratory into quantity production in a matter of months. Refinement was sacrificed to availability; whatever the component, if it worked some of the time it was used. Since then, the call has been for reliability over a range of temperatures sufficient to ensure efficiency from the Equator to the poles.

Transmitter power has been greatly increased and at the same time the noise figure of receivers has been greatly reduced. The noise figure of a typical wartime centimetric radar was 20 db above KT_0F, but already an equivalent radar is considered poor if it cannot achieve 10 db or less. This is as good as a tenfold increase in transmitter power, and it costs a great deal less. Additionally, in large ground installations, modern amplifier techniques permit the theoretical minimum receiver noise figure of a db or two to be approached, offering almost another tenfold improvement.

The best illustration of the meaning of these figures is in consideration of the relative performances of radar at the end of the war and now. The early-warning radar of World War 2 was the Chain Home floodlighting system supported by rotating fan-beam centimetric search radars. The C.H. equipment might give warning at 300 miles. The best centimetric radars were giving perhaps 150 miles.

The mighty U.S.A.F. Ballistic Missile Early-Warning System (BMEWS), with installations in Greenland and Alaska, now uses four large detection radars and three tracking radars. Both types give ranges of no less than 3,000 miles on small targets. The detection radars have fixed parabolic reflectors 400ft long and 165ft high. Electronic scanning permits each detection radar to cover an azimuth of 30 deg so that a sector of 120 deg can be covered by giving each of the four an appropriate line of shoot. The tracking radars have a rotating 90ft parabolic reflector housed in an inflated radome of some 150ft diameter.

Peak power of World War 2 radar was of the order of one megawatt. It is reported that these new radars have an average power of more than a megawatt and that they operate over a wide band extending from S-band to V.H.F. frequencies. It has also been announced that laboratory systems are available to provide ranges of 10,000 miles on small targets and 25,000 miles against larger ones. Should the reader with wartime radar in mind be sceptical of such figures, it may be said that radar contact has been established with the planet Venus at a range of 28 million miles and that it is forecast that it will be possible to track a satellite equipped with a radar beacon out to 500 million miles.

A network of nine stations for tracking satellites without active radar transmitters has been set up across the southern United States employing three groups of three stations each. The centre station of each group uses Doppler tracking techniques and has a transmitter producing a fan-shaped beam to illuminate the satellites. The other two stations of each group are located 250 miles on either side of the transmitter and are receiver stations only. The relative phase of the energy reflected from the satellite and received at each of these stations is detected to establish the satellite's position.

To provide beam-riding guidance for an ICBM, engineering of a very high order is necessary. If a radar tracker is to determine the position of a missile with an accuracy of better than one part in 100,000—and this is stated to be possible—the whole radar has to be housed in a radome in which the temperature is controlled to within half a degree. Some parts of the bearing race on which the radar rotates are said to be machined to tolerances of 50 millionths of an inch.

It will be seen, therefore, that the coverage and accuracy of radar systems can be enormous. So, too, is the cost of the kind of system just discussed. A figure of $720 million per site has been suggested for the BMEWS and from this it will be appreciated that such installations must be supplemented by other smaller and mobile tactical radars to provide a full defence system.

Interpretation of radar information is also of importance. Moving target indication (M.T.I.) has now become an engineering proposition. Moving targets and stationary objects can be separated in such a way that an aircraft flying over a mountain can be seen after the echo from the mountain itself has been removed, even though the original echo may have been a thousand times more powerful than the response from the aircraft. When it is remembered that such a radar system makes measurements every millisecond or so, during which time an aircraft at 600 kt will move only 10in, and that the hill may be covered in trees moving in the wind, the success of M.T.I. must be agreed to give a measure of the present abilities of electronics.

The general problem of the wartime radar was that it gave the ground controller only a fraction of the information he wanted, together with much extraneous clutter which he did not want. World War 2 ground-controlled interception (G.C.I.) equipment used a plan position indicator (P.P.I.) on a cathode-ray tube, the central area of which consisted largely of ground clutter beyond which aircraft appeared as small luminous arcs. Height-finding was done independently and a rudimentary identification of friend from foe (I.F.F.) was used to minimize attacks on friendly aircraft. The controller really needs information giving the position and height of his enemy and the plan position and height of his own aircraft, together with a positive identification of each. He does not wish to be disturbed by ground clutter and interference, nor does he in general wish to see echoes from rainclouds, although it may occasionally be convenient to know the location of turbulent storm centres so that he can ensure that the final stages of his interception do not occur in such an area.

Post-war radar developments have largely solved these problems. Volumetric-scan or "3-D" and monopulse radars have been developed to measure range, height and bearing simultaneously, using electronic scanning methods to give very high data rates.

Monopulse techniques are employed in most modern fire-control and attack radars, perhaps the first production application being in the tail-gun radar of the B-52. Outstanding examples of volumetric radars for defence are the Metrovick tactical radar which forms part of the British air defence system and the Type 984 aircraft direction radar aboard H.M.S. *Victorious*. The latter can acquire height information without tracking a target so that slant range, pointing angles and target height can be obtained during normal surveillance operation. Type 984 transmits probably about two dozen narrow beams stacked vertically and covering a total arc of about 50 deg. One of the beams, at about 25 deg above the horizontal, is of a different frequency and is fixed in elevation for use in long-range early warning. The other beams sweep vertically over small arcs to afford fine discrimination for accurate height-finding. Each beam has a separate receiver channel with automatic frequency control, and the energy is focused by a microwave lens about 14ft in diameter. Pye Ltd. produced the data store, interception computer and display system associated with Type 984 to form a complete defence system. Performance during exercises has been most impressive.

AVIATION ELECTRONICS

Radio Warfare. Electronic countermeasures have now become a critical part of military activity both in peace and war but, not surprisingly, little can be said about the unceasing cloak and dagger activity which it involves. More accurately called radio warfare, it includes three main directions of activity, reconnaissance, decoy and jamming, all of them requiring continuous development of specialized equipment and the utmost subtlety and cunning in operation. The work continues in peace as well as war, and one indication of the scale of radio warfare activities since World War 2 is that the American Services have lost several dozen aircraft shot down while performing such duties, and these must represent but a fraction of the number of missions flown.

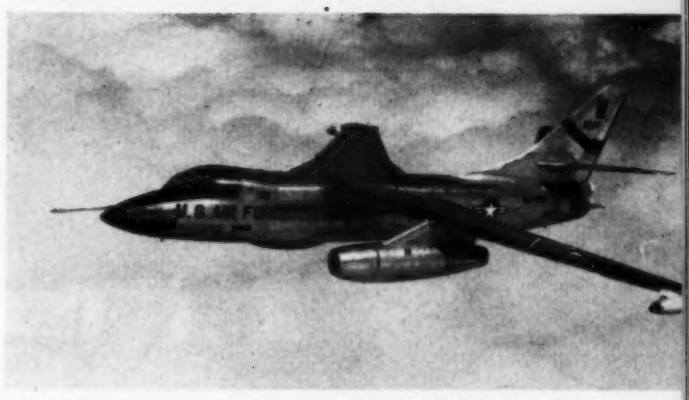
It is obviously essential that the location and characteristics of enemy defence electronics of all kinds should be accurately known before a shooting war starts. To obtain such information, special panoramic receivers can be carried in aircraft and taken sufficiently close to installations to detect the frequency being used and to analyse—in some receivers automatically—the type of transmission involved. The location, type and power of the transmitter can then be fairly accurately gauged. A special transmitter has to be developed to produce jamming signals which will interfere with, or actually swamp, the enemy signal. Conversely, some means can be found of feeding the enemy station with misleading information either by using corner reflectors or such devices as Luneberg lenses to give a mere motor launch or small aircraft the appearance of a threatening battleship or large bomber. Strips of metal foil of a length suited to the transmitted frequency may be dispersed from aircraft, rockets or decoy missiles to produce spurious reflections over a wide area to mask the individual intruder.

Both reflectors and "chaff" can confuse an enemy radar, but they inherently reveal the presence of some threat. Their use in peacetime would generally be taken as an aggressive action, certainly as a warning of unfriendly activity, and it has been stated in the U.S.A. that jamming of the northern early-warning chains might well be taken as an implicit declaration of war. In general, it can be said that jamming can take many forms, being either broadcast or specifically directed at the enemy transmitter, and that it can produce a variety of interference patterns on a radar screen. It is also true that for effective jamming the intruding transmission must have more power at the enemy receiver than the normally returned signals. In many cases, therefore, extremely high jamming powers are needed.

It is now considered that electronic countermeasures can form a much more effective defence for a bomber than the traditional defensive gun armament. A suitable receiver in a bomber will, for instance, momentarily receive transmissions as a search aerial sweeps the sky around the bomber. When signals are received constantly it can be taken that the radar is locked-on and the time has come to take evasive action or to set countermeasures in operation. U.S.A.F. F-100Ds carry such a receiver which will indicate to the pilot the bearing and range of an intercepter radar. It is, of course, possible to apply detection and countermeasures in the form of jamming or decoys to radar-homing intercepters or missiles. Broadly speaking, the more sensitive a detection radar is, the more susceptible it is to jamming signals.

The scale of radio warfare can be judged from the fact that in one post-war year the U.S. spends more on electronic countermeasures than it spent during the whole of World War 2—even during World War 2 the German air defence system was almost swamped by Allied countermeasures and thousands of German scientists were engaged in trying to break the stranglehold. Listening and probing, bluff and counter-bluff, jamming and counter-jamming, formed a constant wily background not only in the air but on land and sea as well. Although research and development must play a very considerable part in this process, it should not be forgotten that the human element is just as important in the game as the specialized equipment itself. Industrially, the problem is specially difficult because new equipment is constantly required. In this field, more than in any other, there is a case for amalgamating the research and production installations so that every operational equipment emerges straight from the experimental workshop.

Test Equipment. Yet another way in which electronics is necessary to military aviation is in the provision of testing and checking systems. Complex and sensitive test apparatus is used, for example, to make certain that a missile on the ground is fit to be launched. Pre-launch testing for some firings in America amounts to 10,000 individual measurements and takes a period of several hours. Accuracy of these measurements and the speed at which they can be made and correlated is of paramount importance and the job could not be done in the time available without the use of specially designed electronic equipment. In fact, as the complexity of testing has increased and the time allowed for its completion has decreased, it has become necessary, as it were, to invent an "electronics inspection engineer," capable of working at the necessary speed without tea breaks.



This Douglas RB-66C is a specially modified version of the tactical bomber specifically intended for electronic counter-measures work

Electronic computers can also greatly reduce the calculation time in the design of the aircraft and missiles themselves. Even in designing a computer another computer comes in handy and it has been said that "we have now reached the stage when computers can reproduce themselves—fortunately none of them so far has shown much inclination to do so." Simulators, too, have been developed to an advanced degree for the training of aircrew and ground staff with much consequent saving in conversion and continuation training time.

Components. It will be seen, therefore, that the fourth phase in the history of electronics for military aviation is very largely that of the improvement and stabilization of World War 2 devices, with the vast improvements in application which the acquisition of computer techniques affords. There have also been other major technical improvements. particularly in the standard of components available for use at wide ranges of ambient temperatures. Resistors, condensers, inductors and transformers to operate at temperatures from −70 deg C up to 200 deg C have been provided and at the recent S.B.A.C. Show at Farnborough one manufacturer announced that components suitable for operation at 500 deg C were under development, as they are in the U.S.A.

Finally, the transistor is now available in reliable production quantities and it can do most of the jobs of the thermionic valve. The latter obtains the free electrons required in electronics by boiling them off a suitably treated wire filament. The heat generated in the boiling process is largely wasted and constitutes the main power drain in most electronic equipments, but the transistor maintains free electrons in a small volume in quite a different way. It is small, it calls for less power consumption, and it does not generate unnecessary heat. All these factors are of major importance in an aircraft or missile, and the transistor will clearly realize its greatest potential in airborne applications. Particularly at great altitudes, the saving of unnecessary heat dissipation is critical because above, say, 70,000ft, radiation becomes the only way of disposing of generated heat. Weight and volume is added to electronic equipment merely to get rid of heat, for example, by the provision of cooling fins or closed-circuit blower and heat-exchanger systems.

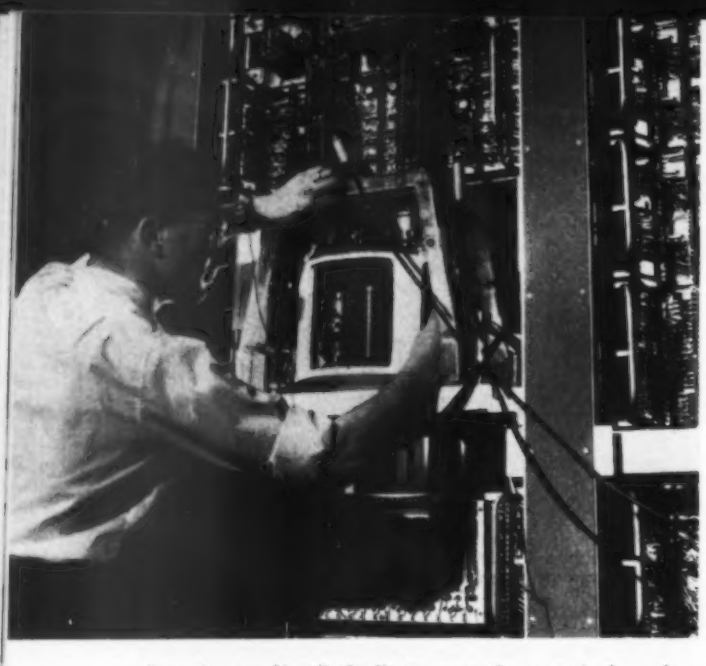
Some idea of the combined value of these new developments can be found by looking at the case of an airborne search radar. In 1949, one such radar comprised seven units, weighed 150 lb, and had a range of 40 miles. By 1959, a radar of only one-quarter the peak power radiated by the earlier model, but having an improved system gain provided by general technical advances, by the improvements of R.F. noise factor and by the provision of higher aerial gain, is giving a range of 150 miles in a set-up having only three units and weighing 56 lb. The reduction in weight and volume has been made possible by the use of transistors and other components and techniques developed since the war.

It remains to repeat that this survey is based only on material publicly available. It is to be presumed that much lies below the surface which has yet to be disclosed. In conclusion, one may perhaps venture the opinion that in this era in which the electronics engineer may take much pride in the power of his achievement, the best service which he can offer to the community is the provision of adequate communications so that ideas may be disseminated through the iron curtains of the world to prevent these terrifying military systems from ever being employed in anger.

Computers •

DIGITAL AND ANALOGUE

BY DR. L. C. PAYNE
(Decca Radar)



An engineer making final adjustments to the magnetic drum of an English Electric Deuce digital computer

COMPUTERS are probably used more in the aviation industry than in any other. In fact, they are indispensable to it and the present state of the aviation art could not have been achieved without their use. This is an astonishing fact when one recalls that both the electronic analogue computer and its more versatile companion, the electrical digital computer, are little more than ten years old. Computers are an essential and much-used tool in the investigation of the structural, aerodynamic and propulsion characteristics which precede the drawing-board stage of a new aircraft. Computer-controlled machine tools have been developed in several countries, including the United Kingdom, for automating the production of complex components used in aircraft construction and are beginning to find their place in the aircraft factories. Computers are an essential part of controlling supersonic fighters and missiles in the air defence system, and they are already being used in the control of civil air traffic and in blind-landing systems. Not least, they are also to be found in the aircraft cockpit for facilitating the use of navaid data and weapon control.

To understand why computers have so quickly established themselves in such an extraordinary diversity of applications, which is by no means confined to the aviation industry and which will certainly continue to grow, it is necessary to examine the relatively few basic principles which underlie the complex system engineering. The name computer suggests a box which takes numerical data and computes from it, according to some formula, a result which may be a number or set of numbers. This conception of a computer, however, while quite valid, is not fundamental enough. It is merely a particular case of what has more appropriately come to be called a "data-processing" machine. This nomenclature rightly emphasises the essential nature of the modern computer which accepts data, numerical or otherwise, and "processes" it by operating on it according to a well-defined set of rules to produce required outputs.

The set of rules describing the process may or may not be a mathematical formula; it may be much more general. It may, for example, be the set of rules by which the drawing dimensions of an aircraft component are translated into the positions of the cutting tool which machines the component. This important point and its implications will become clearer from a description of the overall organization of general-purpose digital and analogue computers (or "data-processing machines").

Essentially a typical general-purpose computer consists of a number of elementary units as illustrated in Fig. 1. Each of these

Fig. 1. Elementary units of a general-purpose computer

units is an elementary computer in the familiar sense: the adder-subtractor computes the sum or difference of two numbers, the multiplier computes the product, and the divider computes the quotient. It may seem that much more than this is required to complete the description of a machine which has been compared with the human brain and has indeed achieved numerical feats well beyond the capability of any human being. But this is not so, and the reason will be almost obvious once it is pointed out that the great advances in pulse circuitry during the war in connection with radar enabled post-war technologists to construct such units which would work about 1,000 times faster than hitherto. This means that whereas an ordinary desk machine might take a second or so for each arithmetical step, its electronic counterpart takes one millisecond. A formidable computation chore, therefore, involving say a million arithmetic steps, which would take a desk machine operator about one million seconds, or 280 hr, could thus, overnight, as it were, be achieved electronically in about 17 min; a task taking 28 hr, representing about a week's work, could be performed in less than two minutes!

Clearly, to feed numbers into such units at the rate of 1,000 a second one cannot use a human operator, and indeed the digital computer as we know it today is simply an arrangement for feeding numbers to such units at the right speed and in the right sequence. Any task which can be broken down into a sequence of arithmetical steps can be performed by a computer. Unlike the human-being operating the desk machine, who can be relied upon to use his intelligence regarding the scaling of intermediate results and so on, once a calculation has been outlined to him, the entire sequence—or programme as it is called—must be set out explicitly for a machine. This task can, and often does, take a very long time—which, depending on the problem, may vary between days, weeks and months. Once it is done the digital computer will race through it at a speed which greatly surpasses that of a human operator. In principle therefore, a digital computer will do no more than can be done on a desk machine. But it is surprising what can be done by a degree of improvement when the degree is large enough. If, as has been done, the rules of chess can be set down as an arithmetical sequence and an arithmetical criterion found for the optimum next move, a computer can race through a hundred possible moves and produce a number defining the next move in what appears to be no time at all. It is for these reasons that the machine has captured the public imagination, but a more critical insight into its modus operandi quickly sets it in perspective. As the Countess of Lovelace, an able mathematician of the last century, remarked about Charles Babbage's conception, when he was attempting the impossible by trying to build a mechanical digital computer 100 years ago, ". . . the engine has no pretensions whatsoever to originate anything; it can only do whatever we know how to order it to perform."

Most of the computers in the aircraft industry at the present time do arithmetic about 1,000 times faster than a desk machine. But machines are being produced today which are between 100 and 1,000 times faster still and at the end of this review we shall briefly refer to the exciting possibilities opened up by this further degree of improvement.

It is not possible within the framework of this article to discuss the many details of computer design and programming technique, but an outline can be given of the organization of such a machine. This is illustrated in Fig. 2. The initial data of a problem, together with the programme, is coded up in a form acceptable to the machine, which usually means punched paper tape or cards, or suitably polarized magnetic tape. This is fed via the input unit into the store which can be regarded as a set of registers, or

AVIATION ELECTRONICS . . .

"words" as they are often called, each capable of retaining data in much the same way as a desk machine keyboard. The main characteristic of storage is its "access" time, by which is meant the time to extract a number to route it to the arithmetic unit. Clearly this time must match the speed of the basic units if the factor of 1,000 is to be maintained for the overall calculation. The main advantage of ferrite core storage, for example, is that it has an access time of a few millionths of a second, which is what is wanted for feeding arithmetic units working nearly one million times as fast as a desk machine. Once the data and programme is fed into the machine, the start-button is pressed and the control unit takes over. It decodes each step of the programme in sequence and routes numbers in turn through the prescribed arithmetic unit.

The entire calculation is thus performed without human interference, each step being performed in milli- or microseconds depending on the particular machine. Intermediate results are stored in part of the store not occupied by the programme or initial data. The final results, still under programme control, are fed into an output unit—such as a tape punch, typewriter, digital data link, D.C. voltage for positioning a machine tool or other system.

As a simple example, frequently used in practice, consider the problem of finding a square root or a logarithm. These can each be expressed as a sequence of simple arithmetical steps by means of the relationships,

$$(1)\ x_{n+1} = \tfrac{1}{2}\left(x_n + \frac{a}{x_n}\right)$$

$$(2)\ lcg(1+a) = a - \frac{a^2}{2} + \frac{a^3}{3} - \frac{a^4}{4} + \cdots$$

Equation (1) expresses the fact that making any guess x_n (subject to certain mathematical niceties which are omitted) at the square root of a, then a better approximation is given by $\tfrac{1}{2}\left(x_n + \frac{a}{x_n}\right)$ which is an arithmetical sequence. Equation (2) describes an obvious sequence. Each of these tasks would be performed in milli-

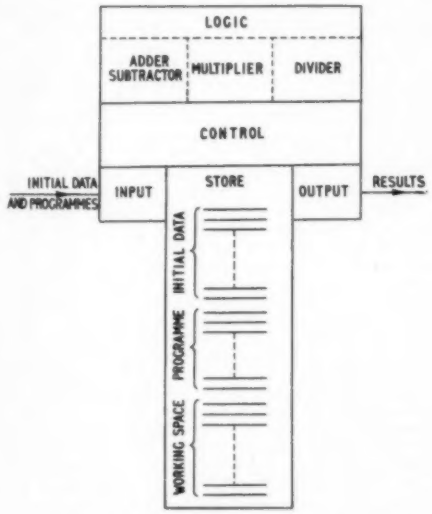


Fig. 2. An outline of computer organization

seconds, which is why one allows the machine to manufacture them *ab initio* during the course of a calculation rather than by referring to a stored table which requires extra storage and generally extra time. Though it might be said in each of these cases that the computer is producing square roots and logarithms, it can be seen in fact that it is merely doing very quickly what the programmer, with the aid of expertise in numerical analysis, has "ordered it to perform." Hence the possibilities and limitations.

One more point should be added. It concerns the nature of the basic logical units. Although at the present time these are most commonly arithmetical units as described, this is by no means necessary. In more specialized applications—such as, for example, the digital differential analyser and character reading machines—the basic logical units are respectively chosen to fit the needs of integration or pattern detection more efficiently. There is nothing sacrosanct about arithmetical units; the data could be processed

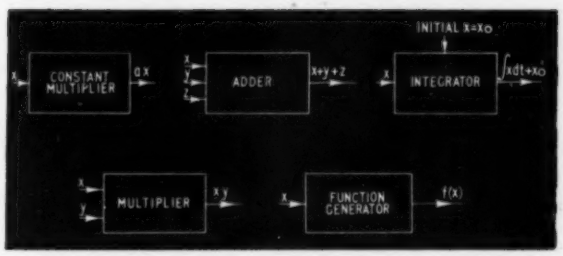


Fig. 3. Basic units of an analogue computer

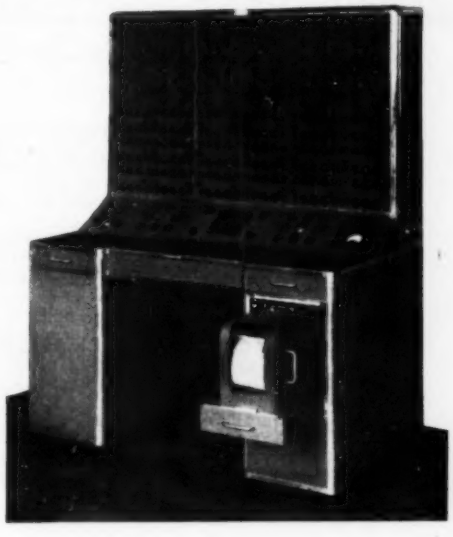
through any convenient choice of logical units if the application warranted it. The overall organization would be very similar to Fig. 2, i.e. the data would be sequenced in a time-multiplexed fashion under the control of an internally stored programme (which may or may not be changeable), but the overall process performed on the data may have very little or no similarity with a conventional computation. In fact, this is the case in character-reading machines. This underlines the point mentioned earlier, that the digital computer is simply a particular case of a data-processing machine in which the "logic" happens to be arithmetic.

To sum up then, a digital data-processing machine can perform any task which can be set down as an explicit sequence of steps through one or more elementary logical units which may or may not be arithmetic.

The comparable main advance since World War 2 in the analogue field is the electronic differential analyser. As its name suggests, this is not a general-purpose computer, and even less a general-purpose data-processing machine. To this extent it is a much less versatile machine. But, for the range of problems that can be set up in the form of differential equations, which circumscribes a great many physical processes used in the aircraft industry where many such machines are to be found, it has a number of useful advantages. There is, in fact, a real need for both analogue and digital methods, and the choice for any particular case can usually be decided without difficulty.

As the name suggests, currents and voltages used in the analogue machine have a direct analogue with the problem to be solved. The basic units are (usually) those illustrated in Fig. 3, which shows the relationships between input and output voltages. Although some of these units are functionally similar to those of the digital computer, there is a very real difference in the manner in which the numbers are handled and represented electronically. The implications of this are discussed later in this article. An example of how the units can be interconnected is shown in Fig. 4. The left-hand side shows a mass acted upon by a spring (force = $C \times$ displacement), a damping element (force = $B \times$ velocity) and

A Short analogue computer used for the solution of differential equations and simulation of actual physical systems



Ferranti Perseus digital computer with magnetic tape and punched-card units. The technician has removed a plug-in element

AVIATION ELECTRONICS . . .

an applied force F(t) which varies with time. The equation relating the displacement of mass with time is,

$$M\frac{d^2x}{dt^2} = \textit{total forces on } M = F(t) - B\frac{dx}{dt} - Cx$$

This equation has its analogue in the relationship between the voltages shown in the right-hand diagram. A voltage $\frac{d^2x}{dt^2}$ produces $\frac{dx}{dt}$ and x after two integrations; these are then added (due respect being paid to signs, co-efficients and scaling which have for simplicity been ignored) to satisfy the equation of motion. In many examples the rate at which the analogue solution is developed can be matched exactly to that of the physical system it represents; in such cases it can therefore replace the physical system, i.e. be used as a simulator. This is particularly valuable where physical experiments are expensive, dangerous, or even impossible; examples are simulating flight trials of new aircraft, or missiles, or exercising the air defence system against a missile threat.

Each unit is made up of an arrangement which includes a high-gain feed-back amplifier, a number of potentiometers and, possibly, condensers. The most general-purpose analogue computer permits plug or patch-board interconnections to be made between these components to form groupings of the units directly analogous to most types of differential equation. Once this is done the solution to the entire equation ($x=x(t)$ in the above example) is available as a function of time. The solution is not built up in a set of discrete steps, each taking a finite amount of time, as it is in the case of a digital computer. Using the above example again, the difference is exactly that between using numerical analysis and a desk machine to solve $M\frac{d^2x}{dt^2} + B\frac{dx}{dt} + Cx = F(t)$, and using an analogous electronic model. Different interconnections in the analogue case alter the model to adapt it to different (differential equation type) problems; different programmes, or sequences in the digital case, change the arithmetical procedure to adapt it to different problems of a much wider class than just differential equations.

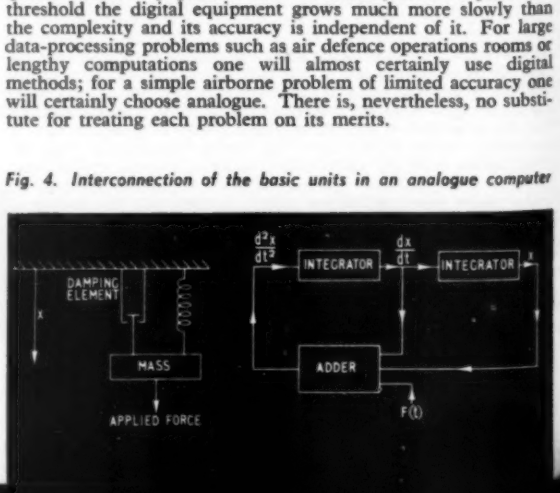
To sum up, an analogue data-processing machine can perform any task which can be set up as an analogue model formed from the inter-connection of a number of basic units, which may or may not be arithmetic.

Digital Versus Analogue

Before describing the part played in every important aspect of aviation by the above types of machine, it is useful to classify some of the more important differences and similarities between them. The fundamental difference between them, which underlies all their relative advantages and disadvantages, is the manner in which data is represented electronically. In an analogue system a number is represented directly by a voltage or some other physical quantity; for this reason the accuracy of an analogue device is directly related to the engineering tolerances and is thus limited to about 0.1 per cent for simple set-ups, which usually decreases to about 1 per cent for complex set-ups involving many interconnected stages. If a system deals with a range of 100 Volts to an accuracy of 0.1 Volts then a number can only be represented to three decimal places. In a digital system, on the other hand, a number is coded in a radix language. For example, in the decimal system (radix 10) only ten voltage levels are required. If pulses of a maximum of 10 V are used then the numbers 0, 1, 2 to 9 could be represented by 1 V levels: two such pulses, adjacent in time, could be used to represent all numbers between 00 and 99; ten such pulses for numbers between 0,000,000,000 and 9,999,999,999; only 1 V levels would be involved. For these reasons the accuracy of a digital device is independent of the engineering tolerances because, once reasonable tolerances have been assigned on the basis of the components being used, the coding can be chosen to represent a number to any required degree of precision. It may appear from this that all systems are digital but some are more digital than others. This is in a sense quite true, but the difference in engineering technique between direct-analogue and coded-radix representation is very real. The radix of two, or *binary* system, is by far the commonest because two-state devices, which are stable in each state and can quickly be switched between states (for example valves, germanium diodes, ferrite cores, etc.) feature most commonly in engineering. The difference in number representation will explain why analogue systems are drift-prone and need periodic setting-up to preserve accuracy; on the other hand because numbers are represented more simply, analogue machines are often faster in operation; they do not involve the finite times between pulses. Also where numbers have a direct analogue, solutions can be displayed more readily than is the case with digital systems. This is a point of some importance in research problems where one is anxious to see the effect of changing parameters.

Although the discussion has been confined to general purpose electronic computers, it needs to be mentioned that it is possible to design analogues of many processes other than differential equations; examples are missile performance, engine performance, flight and radar characteristics, and so on. But with analogue systems the amount of equipment increases with complexity and the accuracy tends to diminish. On the other hand a certain threshold of digital equipment, which may not be small, is required before any problem can be solved, while beyond this threshold the digital equipment grows much more slowly than the complexity and its accuracy is independent of it. For large data-processing problems such as air defence operations rooms or lengthy computations one will almost certainly use digital methods; for a simple airborne problem of limited accuracy one will certainly choose analogue. There is, nevertheless, no substitute for treating each problem on its merits.

Fig. 4. Interconnection of the basic units in an analogue computer



COMPUTERS IN AVIATION

Research, Defence and Automatic Control

THE characteristics and capabilities of digital and analogue computers are summarized in the foregoing article (pages 370-372), which should be regarded as an introduction to the following description of specific applications of computers in aviation. Dr. L. C. Payne here deals first with computers in research and development. Readers who wish to pursue the subject further are referred to two of our sister-journals. "Aircraft Production" has devoted a great deal of attention to the automatic control of machine tools; and "Data Processing" is a specialist journal dealing with commercial aspects of automatic computation.

AS far back as 1952 the S.B.A.C. set up an Electronic Computers Panel to standardize the form in which problems "involving a considerable amount of computation and which occur frequently in the aircraft industry" are presented to digital computers. It would take a large volume to describe all the different kinds of work that have been done, but some idea can be gleaned from a survey of the programmes which actually exist. They can be grouped under several main headings. The first includes the stresses and deformation effects due to loading and temperature; the second the effects, in particular vibrations, induced by aerodynamic forces over the projected speed range; a third the dynamic response induced by the controls or external disturbances of weather and landings; and a fourth, engine and flight performance calculation. This list is by no means exhaustive. Most of the calculations involve specialized mathematical formulæ which are first reduced to extensive but simple arithmetical procedures by means of sophisticated numerical analysis. These are then coded up as programmes for digital computers, which are universally displacing the analogue machines for problems which are large and/or require accuracy beyond a few per cent. In the design of complex engineering structures, such as an aircraft wing or fuselage, it was not possible before the advent of the electronic computer, on an economic time-scale, to analyse all the possible design alternatives. Decisions were taken on an adequate but less than exhaustive exploration and engineering tolerances designed with liberal safety factors to allow for incompleteness of design study. Greater efficiency in structural techniques and use of materials is thus a consequence of high-speed calculation. The analogue machine serves its purpose, not where accuracy or large-scale computation is required, but where the characteristics of a calculation need to be *observed* in order to discover the effects of changing parameters. By turning a knob and examining the resulting change in the waveform solution it is possible to isolate the critical or singular points of a calculation for more accurate examination by a digital machine. Computers are thus used both in the exploration of design alternatives and in the accurate and speedy determination of the design chosen.

Another application of comparable importance is simulation. This, like computation, is also a data-processing exercise in that it involves manipulation of input signals to produce required output signals. The distinctive difference is that the speed of operation corresponds to the true time of the process being simulated. One of the best examples is the flight simulator. By simulating the interactions between different aircraft parts (such as control surface deflections) induced by projected systems (such as control mechanisms, autopilots, etc.) it allows hundreds of "test flights" to be made on the ground. This is cheaper, and far more manageable, than real flights for experimenting with early designs. It allows the marginal behaviour of the aircraft to be tested without hazard. It can also be used for training personnel in new techniques of navigation or weapon technique under controlled conditions. Usually simulators are based on analogue techniques because the accuracy requirements can generally be met, the interactions can be simulated by simple circuit analogues and they are fast enough for real-time working. The faster digital techniques now being produced, however, will lend themselves to building quite sophisticated models operating on a real-time basis, and one may therefore expect them to be used in conjunction with analogue peripheral devices to simulate systems of much greater complexity, e.g., to exercise the air defence control rooms in a missile threat environment.

Quite apart from the many technical calculations involving complicated mathematics, and the many systems engineering integration problems requiring system simulation, computers are used even during the early stages to assess the operational effectiveness of an aircraft. In this assessment the take-off, climb, cruise, descent, holding and landing characteristics of the aircraft are used to calculate fuel consumption, flight times, payloads and costs over specified routes for potential airline operators. Programmes exist for this so-called "route-analysis" problem. It is clearly a part of the more general activity known as operational research, where an increasing number of computers are being applied and which includes the entire sequence of logistics, maintenance, seat reservations and so on required to keep a large fleet of airliners operating efficiently.

Automatic machines are not new. They are common-place items in the motor-car, canning, refrigerator and other industries where the techniques of mass-production are applicable so that designs can be laid down over a period sufficient to cover the special tool development and transfer line lay-outs, and where production is in sufficient quantity to make this expensive and time-consuming process economic. But neither of these important conditions obtains in the aircraft industry, where the customer expects the latest factors affecting safety, speed, manœuvrability and so on to be incorporated in the aircraft he orders. Furthermore, design specifications, such as those affecting aerodynamic smoothness, high-strength structures in thin wings and lightweight spars, and gas-turbine blades, are a great deal more exacting. The need is obviously very real here for tools which can operate with great precision and which are flexible enough to meet frequently changing designs. The computer controlled-machine tool meets this need, and not surprisingly therefore is already well established in aircraft production in the United States and, to a lesser but rapidly increasing extent in this country.

A group of three Short analogue computers linked to a mock-up cockpit to simulate the flight characteristics of an aircraft which has not yet been built

Basically the problem is, once again, a data-processing one. The machine-cutting tool has one, two or three degrees of freedom corresponding to each dimension, and the object is to control the movement of the tool so that it machines the contour (which may be a continuous profile and/or a discrete set of holes, of varying shapes and diameters) specified by an engineering drawing to prescribed tolerances. The control signals must take account of the machine characteristics (back-lash, cutter radius, tool deflections) and workpiece material in prescribing the rate of movement. The usual way of realizing this in the mass production industries is to design a number of machines each capable of a

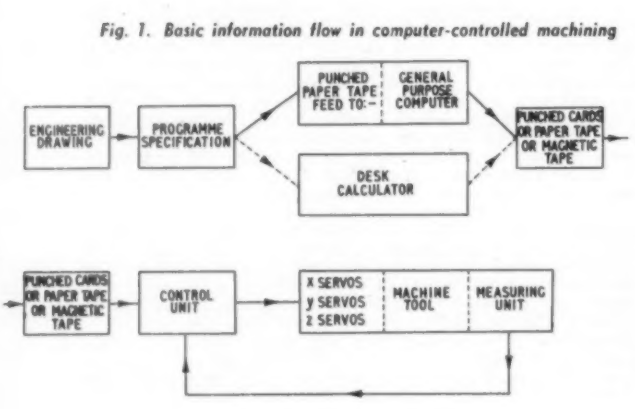
Tape and digital control of a large milling machine evolved jointly by Ferranti and Fairey

AVIATION ELECTRONICS . .

fixed limited sequence of movements. A component is transferred between the machines in turn until the design specification is met. More complex specifications are met by investing skilled effort and time into machining a master template and using copies of this to control machine movements. This latter is obviously a step in the right direction; the template effectively embodies the engineering drawing information in a form the machine can accept, but even so it is expensive and time-consuming to produce and still requires human supervision to control the machine tool. Computer-control eliminates the need for skilled operators and, in many cases, particularly for complex specifications, is more economic than template procedure.

To anyone acquainted with the fundamentals of data-processing machines, as described in the preceding article on computers, the possibility of computer-controlled machine tools is obvious. Perhaps it is not surprising therefore that the earliest explorations of this possibility were made about ten years ago at the Massachusetts Institute of Technology, where a great deal of pioneering work in computers was going on, particularly under the impetus of defence programmes. The first system was successfully demonstrated in 1952, being applied to a Cincinnati "Hydrotel" milling machine, and M.I.T. coined the now widely used term "numerical control." The basic information flow is outlined in Fig. 1. From the engineering drawing a "programming engineer" extracts the essential numerical data defining the contour to be machined, and presents it together with other data (such as the cutter radius, feed rate and tolerances required) in a systematically coded form to a general-purpose digital computer.

Fig. 1. Basic information flow in computer-controlled machining



The computer derives from this data a set of signals which are suited to the particular type of control unit. The signals are stored on punched cards, paper tape or magnetic tape and then fed to the control unit, which in turn regulates the power to the servos controlling the movement of the machine tool. A measuring unit feeds back the actual co-ordinates, and it is the difference between these and the prescribed co-ordinates which determines the servo control and completes the closed loop.

The amount of processing to be done by the general purpose computer will depend on the type of control unit being used, and on the complexity of the contour being machined. In certain cases a desk calculator is adequate. In any case a general purpose computer will not be fully loaded by the requirements of one machine tool, and as indicated in Fig. 1, it is likely that the production of the appropriate tape for the control unit will be separated from the machine tool. One computer can be used to produce the tapes

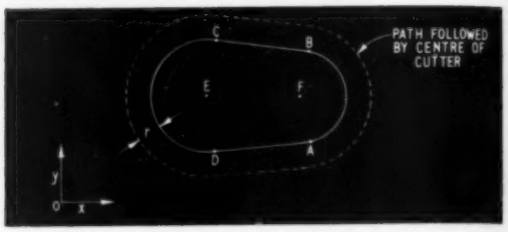


Fig. 2. The diagram above and table below show the programme specification for cutting a simple two-dimensional contour

Contour	Co-ordinates	Circle Centre	Other Data
Line	A (x_1, y_1)		1. Co's origin (x_0, y_0)
Circle	B (x_2, y_2)	E (x_3, y_3)	2. Cutter radius r
Line	C (x_4, y_4)		3. Feed-rate R
Circle	D (x_5, y_5)	F (x_6, y_6)	4. Tolerance 0.01%

for many machines, or producing the tapes for a few machines may be merely one of the tasks which a computer is performing, of which others may be mathematical problems or pay-roll calculations. In fact, time may be bought on a remotely situated computer which will receive the programme specification by post or teleprinter and return the corresponding machine tape.

The most important variation in these machines is whether the control unit employed is basically analogue or digital. In the United Kingdom E.M.I. Ltd. and Ferranti (Edinburgh) Ltd. have successfully developed analogue and digital control systems respectively. In the digital system only the minimum data necessary to specify the contour needs to be fed into the computer. For the simple two-dimensional contour in Fig. 2 the programme specification would be as shown. Even for a turbine blade, or ship's propeller, it is remarkable how little information is required to specify the complete contour. From this data the computer generates all the points at, say, 0.0001in intervals, for the entire path followed by the centre of the cutting tool. Only this data has to be computed; it is reproduced on magnetic tape at intervals specified by the feed-rate R. The digital control unit simply reads this data, together with that fed back from the measuring unit, and regulates power to the servos according to the differences in the two sets of co-ordinates.

The analogue control unit, on the other hand, acts somewhat differently and, for the example illustrated, would in fact make the general-purpose digital computer unnecessary. In fact it includes within itself analogue interpolators for each co-ordinate which generate all the intermediate positions of the cutter path between selected points to which a parabolic curve can be fitted.

Instead of the data shown in Fig. 2 it requires the data shown in Fig. 3. More points are needed than the mathematical minimum; the number being such that each span can be approximated to by parabolic interpolation to within the engineering tolerances specified. The finer the tolerance the greater the number of points. The essential difference between analogue and digital control is illustrated in Fig. 4.

In the digital case all the cutter contour positions are computed before being fed to control, but in the analogue case only parabolic span data is computed before being fed to control, the rest being computed by the analogue interpolators. In the first case a digital computer is always required; in the second a digital computer is only essential for complex contours. On the other hand the control unit part of the machine tool is rather more sophisticated in the analogue case and is required for each machine tool.

Many other pros and cons can be cited, only some of which will

be applicable in any particular case, and the reader is referred to the literature for fuller details. On the whole the accuracy is limited by the machine tool itself (of the order of 0.01 per cent is possible) rather than the particular computing technique.

The main advantage of numerical control is that it eliminates the human element in the setting-up, measuring and control of the machine tool, without sacrificing its flexibility to do very different types of profile. It is thus kept cutting for a significantly greater proportion of time and its efficiency is in fact increased by a factor of upwards of ten. It eliminates human error, and its accuracy is not a function of human fatigue or problem complexity. Numerical control is already established in the aircraft industry and with its potentialities, not least of which is the wholesale mechanization of production from the drawing-board stage, it will undoubtedly extend its application.

Computers in Air Defence

It is almost certain that the most sophisticated use yet made of modern computing techniques is in air defence. For security reasons one can only guess at the elaborate missile performance simulators, the detailed automatic checking sequences that must precede ballistic missile firings, the elaborate guidance elements which set it on course, the complex tracking, telemetry and instrument equipment which collects flight trial data, and the various electronic processes for analysing this data. But from the evidence available, not least of which is automatic control of pilotless target aircraft such as the Jindivik, it is reasonably certain that automatic data-processing is used on a large and complex scale.

The significance of computers in the air defence system can be amply illustrated by considering the formidable data-processing problems with which it has to deal. The first of these is that of determining at all times in a vast region of airspace the precise

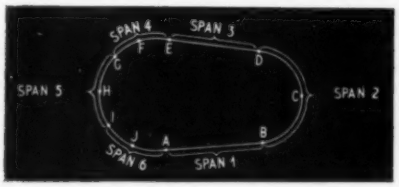
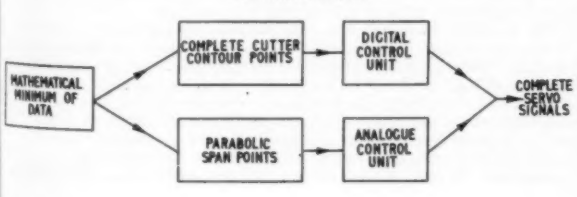


Fig. 3. Parabolic span points for an analogue-controlled machining operation on the same contour as in Fig. 2

position of every target with a high degree of probability. The time available to do this, against a high-speed threat, is short and is complicated, firstly, by the presence at all times of civil aircraft and, secondly, by the ability of the enemy to nullify radar detection by electronic jamming. There is no time for sorting out the radar pictures manually, or for using human intelligence to correlate and filter the wealth of data transmitted from the multiple data sources. The pattern of the methods used for dealing with these problems is set by the American SAGE (Semi-Automatic Ground Environment) system, the heart of which consists of a vast digital data-processing system incorporating the principles described in the preceding article. Data from radar and other detection systems is extracted as automatically as techniques permit and then routed back by direct line and broadcast digital links to a central processing computer. The large number of aircraft tracks is automatically correlated and filtered under the control of specially prepared programmes which take account of all known friendly aircraft movements and, in effect, substantially sort out the air situation in a matter of seconds at most. Only the residue of tracks that cannot be dealt with automatically, either because the basic data is confused by noise or because a friendly movement has not been transmitted to the computer, has to be sorted out by human intelligence. It is only in this way

Fig. 4. The essential difference between analogue and digital control of machine tools



A Wadkin miller fitted with an analogue control produced by E.M.I.

that the air movements of a country or continent can be continually and efficiently monitored. The high speed of the computer, which can do sums in milli- or micro-seconds, really comes into its own here, not because there is any basic mathematical complexity but simply because of the sheer quantity of data that has to be handled in the absolute minimum of time.

Once the target tracks have been established in this way and their identity, speed, course, height and number derived, the data is almost simultaneously presented on electronic displays for assessment by the tactical commander. By pressing the appropriate buttons he can call into operation prediction programmes which enable him in an instant to assess the intention of the threat and determine the priorities for interception. Other programmes allow him or his assistants to assess the impact points and kill-times that would result from assigning fighter type A or missile type B. On this basis he can choose the optimum intercepter to use.

The availability of each intercepter and its state of readiness is also continuously evaluated by programmes processing the statistical data linked from each intercepter and weapon site. The data-processing equipment thus serves him as an efficient *major domo* who assesses like lightning the implications of any tactical decision. In this way the element of tactical discretion is preserved; the computer is the servant, the decisions are human. This is as far as automation goes in current air defence philosophy and practice, and it is of course a necessary and tremendous step forward from the "handraulic" methods of World War 2.

Looking farther ahead, it may well be that there just is not time for human intelligence to act at all. More systematized, less subtle, machine decisions according to the best possible pre-planned criteria will then have to be taken, because only machines can act quickly enough.

Once an intercepter or missile is allocated the computer plays another very important part in computing the necessary mid-course guidance data which is transmitted to the autopilot or missile by automatic data-link. The complete loop from target detection to target interception is thus closed automatically, so that once an interception is in progress the digital data-processing circuit takes over and the radar controller, tactical commander, interception controller and (in the case of fighters) pilot, become monitors only. They are no longer delaying links in the data-handling chain, but can devote their skills to directing the automatic data-flow to accomplish efficient control.

Digital data-processing has other advantages of outstanding operational and technical significance. It is flexible. For example, should flying experience or technical developments demand a change in fighter attack profiles only a change in the interception programme is required, not in equipment. Also, as the emphasis shifts from manned intercepters to missiles the same computing facilities can deal with modified requirements for mid-course guidance. The air defence system can thus adapt itself in some measure to changing requirements, and is less subject to the pertinent American cliché on defence projects that "if they work they are obsolete!" Digital data-processing can to a great extent monitor its own efficiency by using special "test programmes." Something like 50 milli-seconds is sufficient to test most of the basic logical facilities, which means that a 0.5 per cent duty cycle allocation is all that is required to check the system automatically once every ten seconds.

The overall system can be designed to incorporate "dynamic standby" facilities. Instead of having non-working spare units collecting dust in corridors a balanced amount of extra data-processing capacity is built into the overall systems engineering, with the result that at, say, 60 per cent efficiency the system works at reduced capacity; it is not brought to a standstill until a faulty unit is discovered. The reduced capacity can be designed to meet 100 per cent of the actual air battle requirements, thus allowing a high degree of effectiveness based on realistic (i.e., less than 100 per cent) standards of engineering. Moreover the balanced redundancy on which this depends is not a useless margin; it can be used in peace-time to simulate by special programmes a

The computer room in the experimental tactical control centre at the Royal Radar Establishment at Malvern

substantial part of a missile threat environment, so exercising the air defence system.

Digital data-processing therefore admits of a valuable rationalization of equipment. Instead of having extra simulation and standby equipment, of use only in peace-time and emergency, this is built into an integrated design giving a fully operational system, with a margin of flexibility for adaptation to changing requirements, and spare capacity in case of partial breakdown.

Computers in Air Traffic Control

Because of the rapid expansion of air transport in number, variety and complexity of aircraft types, and because of the rate at which potential hazards can be aggravated by the ever increasing speeds involved, the control of air traffic in this day and age poses one of the most urgent and complex data-processing problems. As much as any problem it needs all the benefit it can possibly derive from "automation," yet is conspicuous in dithering on the brink of electronic innovation and in being essentially "handraulic" in its methods of operation. The use of airspace which demands 10 minutes longitudinal separation time in an airway (50 miles for a 300 m.p.h. aircraft) is grossly inefficient and reflects the limitations of the present methods. Introduction of modernization plans is delayed partly for political reasons: establishing internationally agreed standards in civil aviation is a tedious and exasperating business. Another reason is the nature of the problem: since hundreds of passenger aircraft movements occur daily the high, but less than 100 per cent, efficiencies of the elaborate automatic systems such as those used in air defence are quite unacceptable. Finally, inadequate appreciation of automation techniques varies between facile optimism on the one hand and a turgid scepticism on the other. Regarded as panaceas, digital data-processing techniques certainly fail; regarded realistically however, in the context of the systems engineering philosophy described earlier in this article, they can ease the problems considerably.

By reasoning similar to that now to be given, the subject can be set in perspective and the ground cleared for making a significant first advance towards an automatic system. If by automation is meant a system which completely displaces human control in favour of automatic control then, despite the many utterances of well-intentioned automation propagandists, it is safe to say that there will be no automation in civil aviation. The problem is vastly different from that of an oil refinery or a car manufacturing plant. The "electronic brains" which it has been claimed can perform the air traffic controller's jobs have less flexibility than the least intelligent of controllers. Fast though they are at doing well-defined procedures, they have no power at all for improvization or for dealing with emergencies. Their entire capacity has to be pre-programmed and that part of a controller's job which can be made explicit as a set of rules is by no means all of it. It comprises but a token of his judgment, his discretion, his experience, his built-in hunches, which make him react quickly and effectively when new situations arise. No controller can leave a set of rules at his post and expect another, taking cognisance only of the rules, to replace him in any way. In practice, no controller can simply transfer his post directly to another and expect him to take over right away. The newcomer will overlap awhile, to assimilate the air situation before accepting responsibility.

But this need not be a philosophy of despair as it is so often taken to be; it is not tantamount to saying that the new techniques can be of no use. Emergencies are few in number and they alone need the subtlety of human attention; the bulk of the air situation is substantially regular, goes according to schedule and needs only monitoring. The fundamental weakness of the present system is that human attention and concentration is more or less equally divided between all aircraft whether they need it or not, and consequently more emergencies tend to arise because most of the available effort is involved watching the bulk of air traffic. Those, therefore, who advise against any automatic innovation because it cannot deal adequately and reliably with emergencies, aggravate the position by preventing the introduction of systems which could substantially reduce the quantity of work and leave the controller free to apply his special abilities to situations that demand it. This said, it is only fair to add that such attitudes are often reactions to the facile gossip which talks glibly of computer-controlled civil air traffic displacing human decisions.

The computer-controlled machine tool is a very long way from "automatic production control," the punched-card paraphernalia of the office is a long way from "automatic management decisions," and the sophisticated American SAGE is a long way from fighting automatic air battles. The lessons are slowly being learned in each of these fields that the tactical discretion of the air commander and the technical and commercial judgment of the company director, as well as the effective improvizations of the air traffic controller, are beyond replacement by any of the techniques thus far proposed by mathematics, operational research, or digital technology. Distinction must be made between the tools which facilitate control and the minds that use them. What, in truth, can be said is that modern technology has greatly improved and augmented the stock of tools. Properly systems-engineered, in the large area of many problems in which they are valid, they can improve immeasurably the degree of automaticity and effectiveness of control. It is only pre-conceived ideas, of the over-cautious and over-optimistic varieties that stand in the way of progress, and in particular of improved air traffic control procedures.

What does improved air traffic control mean? In a nutshell it means much better use of the enormous amount of airspace, of allowing each and every aircraft that desires it to get from A to B by the most direct route at its optimum cruising speed without delays at terminals and consistent with 100 per cent safety. Automatic data-processing can help by marshalling the data specifying aircraft positions, speeds, altitudes, types, identification labels and by switching it to suitable displays for human decisions and human control. Alternatively, it can be switched to other boxes for automatic control monitored by human controllers who can call on prediction programmes, and other aids to assess conflicts and interpose emergency or avoidance procedures.

Before this can be done, or is worth doing, the data must be available in a form in which it can be assimilated digitally. The present system of data collection, which is predominantly that of pilots verbally reporting their position over isolated beacons, must therefore be substantially supplemented by other means. Beacon reports are far too infrequent; they are also pretty inaccurate by the time the pilot has established radio contact and delivered his message; moreover the bandwidth taken up is out of all proportion to the information content. Present separation standards in fact make adequate allowance for all these deficiencies. The system is far too "open-loop"; little information is received and sent between the reporting points which may be 10s or 100s of miles apart.

Developments are now under way to supplement the present beacon system by radar cover over all the airways. This will certainly give more accurate data more quickly: it will give a consistent and comprehensive picture of the airspace. But if radar is to offer any more than a bonus, if it is to become the basic data feeding a more automatic system, then better means have to be found for extracting radar data automatically. In this context the excellent work of Mr. G. Hinckley's pioneering team at the R.A.E., Farnborough, merits considerably greater attention. In any event, radar information is insufficient by itself; it lacks identity, it is not ideally suited to making rapid height determinations, it gives line-of-sight distances, it is affected to some extent by weather, and so on. But aircraft identity and height are available in the aircraft together with navaid data and although this data is of little use to A.T.C. when given by voice communications, it would have considerable value if transmitted by data-link.

The frequency and accuracy of modern navaid data is compatible with radar data; the one system could therefore augment the other. This would offer valuable redundancy without duplication; the A.T.C. need not be implicitly dependent on either radar or navaid data by itself. Moreover, the navaids need not be identical, which is an important practical consideration. It is envisaged that the ground link-terminal equipment would successively switch to each aircraft within an A.T.C. area and feed the coded data into a computer. If part of the code specified the type of navaid, the

appropriate programme could be invoked to reduce the data to a common co-ordinate system; radar data would be fed likewise and changed from line-of-sight to true plan co-ordinate form. The computer "memory" would thus store all the positional data derived from all sources; which it is suggested would be seeded on a priority basis.

The information derived in this way would form the bulk of data required in normal circumstances and, being coded, it could make efficient use of bandwidth, leaving highly redundant voice channels available for emergency. Separations could be based on, say, three or four levels depending on the quality of data available; if navaids were classified in this way a premium would be placed on the more accurate systems and the politics could be left to themselves. The failure, or partial failure, of a radar or navaid would be indicated by the absence of such data in the computer store and separations could be adjusted accordingly; the change of separation would be notified to the controller so that he could carefully monitor the transition stage.

Such considerations indicate the flexible way in which data-processing can help and illustrate how it can be integrated into a system which shares a great deal of the burden without being autonomous. A fuller description of the more detailed planning for using the data for control once it is marshalled, would take many pages. At all events it is certainly possible to envisage a closed automatic data-processing loop maintaining the bulk of separations between aircraft, in which the air traffic controllers are substantially monitors who interpose control instructions, on the basis of signals from the data-processing equipment, indicating that some change from the prescribed course is required.

Computers in the Cockpit

Computers, of one sort or another, are familiar enough in the aircraft cockpit; they seem to be an inevitable adjunct of each and every type of navaid that exists. Furthermore, modern aircraft range over such considerable regions of airspace that dependence on a single navaid is seldom possible, with the result that the pilot and navigator are confronted with a bewildering set of knobbery and dials from which to sort out the best navigational data at any given time or place.

Considerable thought has been given in recent years to the problem of integrating the *ad hoc* computery of individual systems into a single automatic navigational system. This is certainly a realizable aim with modern computing techniques using miniature components, and many detailed proposals describing possible systems were presented at the Paris Conference on "Navigation and Automation," organized in April 1959, by the combined French, German and English Institutes of Navigation.

Navaids giving position directly are not usually "self-contained"; they depend on signals required from ground installations. Furthermore, the co-ordinates supplied by such systems need transforming before they can be used. Self-contained systems on the other hand do not give positional data directly. Doppler provides rate-of-change of position, and this has to be integrated with respect to time and added to the last "fix" to give current position. The general navigational problem is therefore one of deriving good fix data as often as possible and up-dating this by using such velocity information as can be found. In the most primitive set-up this constitutes periodic dead-reckoning; in the most sophisticated it constitutes automatic and continuous dead-reckoning.

In a (relatively) simple system course is specified by the airspeed indicator and magnetic compass (giving heading referred to magnetic north), and the effect of wind is specified by meteorological data. Groundspeed and track have to be computed. In a Doppler system, the groundspeed and drift angle are specified. If the heading, as given by the magnetic compass, is added to the drift angle then this gives the ground track. Clearly, therefore, a Doppler system is only as good as the heading reference.

If airspeed is added vectorially to the Doppler data then the wind vector can be deduced. Wind derived in this way is generally more accurate than meteorological data, and it is usually computed continuously, so that should Doppler fail it can be used in conjunction with airspeed to give groundspeed and track. In an inertial system, only the accelerations with respect to a stable platform are given; these have to be corrected for earth's movement and integrated with respect to time to give groundspeed. But inertial systems give better short-term speeds than Doppler.

The procedure adopted in practice is to assemble a number of navaids, one or other of which is always likely to be available, and each of which can supplement and correct the other. The computer switches in the best data at any given time and produces continuously and automatically the up-dated versions of position, course, speed, distance-to-go and so on.

These ideas are best illustrated by outlining the details of a particular system, and the one chosen—that of the American B-58 Hustler—is probably the most expensive and comprehensive of its kind ever designed. The primary groundspeed and track data are derived from an inertial platform corrected by mixing it with Doppler-derived velocity data. Heading data is derived from continuous stellar tracking which determines the relative bearing and latitude of selected stars at night and the sun by day. Periodic fixes are obtained by a specially designed radar sighting system which searches an expected locality for known fixes. Taken together the fixes and velocity data allow of continuous and automatic dead-reckoning of current positional data. Furthermore, this is used to compute the distance-to-destination along a great circle course, and fed to a special (interchangeable) computing unit which produces ballistic trajectory data for the bombs, including release point and angle, impact point, etc. The system is entirely analogue and weighs about 2,000 lb.

Such a degree of sophistication is not likely to be found in civil aircraft for some time to come, but it points the way. Micro-miniaturization has passed the dream stage in missile application. Once quantity production gets under way and meets the economics of commercial aircraft then such rationalized computing systems will inevitably be introduced. In any case, the size and cost of modern large jet airliners, as well as their great range, will begin to require them if they are to operate efficiently.

The future trends of computers in aviation have been partly anticipated by what has been said, and as the specifically electronic features are discussed elsewhere, it is only necessary to point out the salient features. Essentially, these are two. The first concerns the speed of digital computing elements. Most of the applications that have been described are based on "first-decade" computers operating about 1,000 times faster than a desk machine. The second decade will see the introduction of machines operating between 100 and 1,000 times faster still. The implications of this are far-reaching. It means, for example, that one machine can be time-multiplexed to control many different types of peripheral equipment, each working in its own time. Electronic displays requiring the renewal of data 20 times per second (every 50 milli-seconds), and automatic digital links controlling aircraft, missiles and radars requiring renewal of data at about the same frequency, can be controlled by signals from the same machine under the guidance of the executive and supervisory programmes in an air-traffic control centre. This is due to the fact that in 50 milli-seconds one of the new computers is capable of as many as 10,000 elementary operations. It also means that digital techniques will lend themselves more readily to simulation, because there will be no trouble in performing calculations in "real time." The greater flexibility (to obey very different types of programme without change of hardware) will commend this approach. The second new feature, already mentioned, is miniaturization. Coupled with the advanced speeds this implies that quite sophisticated operations can be performed by quite small boxes. Digitally coded radio-telemetry as a means of controlling satellite vehicles is but one area where this will be of tremendous advantage. Indeed the prospect for automatic control in many contexts is auspicious, and one may expect an extension of computing techniques in aviation in the next decade no less significant than in the one which has just come to an end.

Environmental testing of the Sperry navigation system of the Convair B-58 Hustler, which carries an integrated computation system

Aircraft Communications

STATE OF THE ART, AND TRENDS SUMMARIZED

IN a review of aircraft communications it is not easy to pinpoint significant developments which have recently taken place, but an examination of existing equipment and an indication of immediate future trends serves to provide a useful overall picture of this very important and specialized field. Communications, like navigation aids and instrumentation, must be taken out of the general picture of aircraft electronics and examined individually, and the dividing line is here drawn as clearly as possible.

It is impossible to compare in detail all the merits of modern equipment with those of the equipment of a decade ago. It is probably sufficient to observe that current equipment has progressed in natural development stages, providing improved signal-to-noise ratios, channel separation, control methods, smaller dimensions and weight and, last but not least, reliability. A large part of all these improvements is attributable to developments in the small components. Reliability and the saving of space and weight have been greatly assisted by the advent of the transistor, improved ferrite materials and printed circuitry. It should be appreciated that the transistorizing of a new equipment design is not simply a matter of replacing the basic valve concept by transistor circuitry: new aspects of design have evolved, particularly in the associated electrical components. The resultant miniaturization introduces new problems of accessibility.

The development programmes of the various manufacturers have been remarkably rapid, but the economic factors are modified by the fact that such designs are only likely to be incorporated in new aircraft types. An airline already using full communications equipment in aircraft which have seen some years' service and are likely to see several more, is not easily sold on new equipment which saves space, weight and electrical power and probably gives better performance, if it is going to cost a lot of money and require additional maintenance provisions.

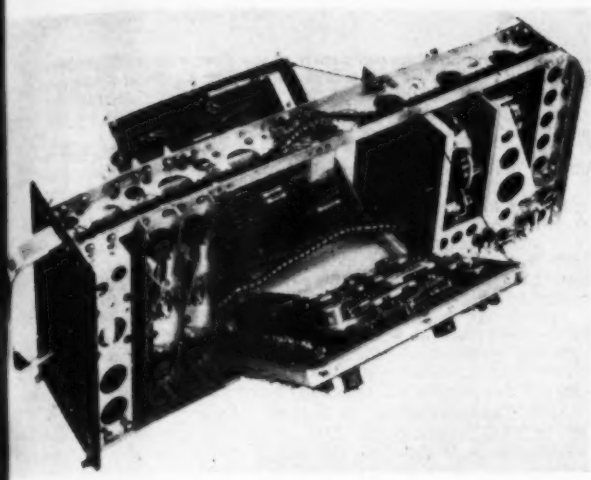
Manufacturers of airborne radio in the United States have for many years adhered to a standard set of form factors for their "black boxes." These cover, in the main, case dimensions, mounting trays, location of plugs and sockets and a system of indexing fouling pins to ensure that only the correct equipment can be fitted in its appropriate rack position. Pin connections on the multiple connectors are specified for individual units, and makers can have their own particular pin connections registered when they differ from the basic laid-down characteristics. The specified plug connections are a function of the facilities provided by the equipment and these are normally well defined and known to all concerned.

Formulation of such standards is one of the functions of Aeronautical Radio Inc. (ARINC), an organization which operates under the aegis of the airline operators, and whose meetings are attended by electronic and aircraft manufacturers. The size of box is based on a standard width dimension called "one ATR" and variations in simple submultiples of this provide a range of case widths. Two case lengths are provided for, termed long and short, and the height is standard. A sample case size specification could read long ½ ATR. A table on page 379 details the various configurations.

The smallest standard case size is a short ¼ ATR, but because of the trends in miniaturization, provision has been made for a possible nominal, half-height configuration which will in future allow duplication by "pick-a-back" instead of side-by-side mounting. It is worth noting that the British Universal Racking System which provides the same sort of standards and has been in use for many years possesses many features which are clearly better and more flexible than the ARINC ATRs. But in the interests of interchangeability, British manufacturers have recently begun to adopt the ARINC form factors and, in at least one recent case, have presented plug connections for registration. In another instance, a complete equipment characteristic has been submitted for ARINC consideration.

Organizations in Britain—among their other functions—operate to assist in the problems of standardization in so far as they affect interchangeability. The Electronic Engineering Association and the Air Transport Electronics Council convene committees to discuss these problems and provide forums for wider discussion of the many aspects of aircraft electronics equipment. A standard system of rack mounting for electronic equipment is under review with the S.B.A.C., and equipment cooling systems associated with such racking have been and are being examined.

Such meetings make no attempt to interfere with the internal design of the equipment itself and leave the individual manufacturer complete freedom for competition within the limits of the



Considerable latitude remains for individual design within the ATR form factors, as illustrated by this tracking unit for Decca Doppler

AVIATION ELECTRONICS . . .

box size. Since the dimensions related to a specific type of equipment have been the subject of careful examination by all concerned, there is no likelihood of their interfering with competitive development.

No attempt is usually made to standardize aerial systems, because performance requirements are generally known and the design of an aircraft, its operating speed and many other factors make individual treatment necessary. Suppressed aerials are almost essential in the newer transports and the only satisfactory method of deciding on their location and design is by close liaison between aircraft and electronic manufacturers.

Because of the low cabin noise level of jet transports, the quality of reproduction from the cabin address system is changing. In high ambient noise conditions the amplifier response is limited to give emphasis to intelligibility rather than high fidelity, but as the background is reduced the emphasis turns towards improved quality of reproduction. High cockpit noise levels in piston-engined aircraft require the use of differential, noise-cancelling microphones. These are of necessity very insensitive, and call for high gain in the intercom. and modulator amplifiers. It seems evident, therefore, that the noise-cancelling microphone might be rejected in favour of at least a higher sensitivity microphone for jet aircraft use, and such a change would require extensive modification of intercom. systems.

A factor highlighted by at least one manufacturer at Farnborough this year is the need for suppression of electrical noise. Although always with us, it has not always been keenly appreciated. Suppression of such interference has largely contributed towards improved range and intelligibility, and is now a highly sophisticated activity in the industry.

On the subject of interference it is also appropriate to mention that, with the introduction of transistorized equipment, transient voltages superimposed on the primary power supply of the aircraft by large changes of load can be of such a magnitude as to destroy or damage transistors in the low-resistance, higher-power electronic circuits. Steps have been taken to provide protection against such hazards and work is in hand to improve the situation, but this shows that the transistor does not simply replace the thermionic valve. It must be apparent, too, that miniaturization and the cost of new equipment is additionally affected.

A subject which continuously comes under review is the maintenance of electronic equipment for aircraft. As the equipment becomes smaller, accessibility tends to suffer and even the most delicate wielding of tools such as soldering irons begins to look rather ham-fisted in relation to many modern components. In the not-too-distant future, equipment might consist of a frame carrying plug-in sub-modules, each containing a full sub-circuit which can actually be thrown away if it fails.

ARINC STANDARD ATR CASE SIZES

	Approximate Vol. (cu in)	Width (in) ±0.0312Sin	Length (in)	Max Height (in)
Short ¼ ATR ...	215	2.250	12.5625	7.625
Long ¼ ATR ...	335	2.250	19.5625	7.625
Short ½ ATR ...	340	3.5625	12.5625	7.625
Long ½ ATR ...	530	3.5625	19.5625	7.625
Short ¾ ATR ...	470	4.875	12.5625	7.625
Long ¾ ATR ...	725	4.875	19.5625	7.625
Short 1 ATR ...	720	7.50	12.5625	7.625
Long 1 ATR ...	1,120	7.50	19.5625	7.625
1 ATR	1,510	10.125	19.5625	7.625
1½ ATR	2,295	15.375	19.5625	7.625

Assuming that each module is easily monitored at input and output, fault diagnosis becomes very much simpler and, provided that each module contains a small enough section of the overall circuit, it could economically be discarded without any attempt at repair. The term "small enough section" may be misleading. Trends in development indicate a possibility of replacing the module consisting of a single amplifying device such as a transistor with all the associated components of its stage, by one containing, say, the whole intermediate frequency amplifier. One imagines that this is a matter for considerable economic study, but it illustrates the degree of progress from the stage where the modules of a communications radio were, in effect, each and every component part.

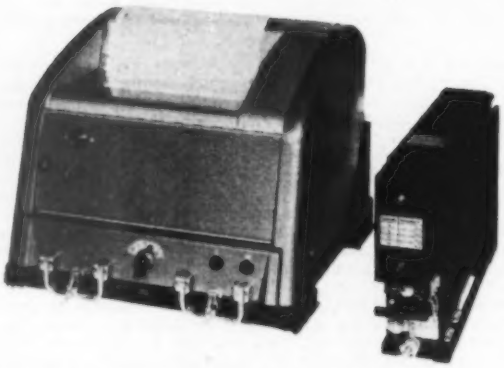
Modular circuitry might lend itself readily to automatic fault-locating, especially if the trouble-shooting apparatus had to diagnose not a small component fault, but only the failure of a main circuit function which, as already suggested, might be performed by a whole series of amplifying stages such as an intermediate frequency strip. The ultimate stage of throwing away faulty module will probably be reached progressively. As an intermediate step, rapid fault-clearing would be used only to indicate which module required replacement; and the faulty unit would then be taken for repair at the base workshop.

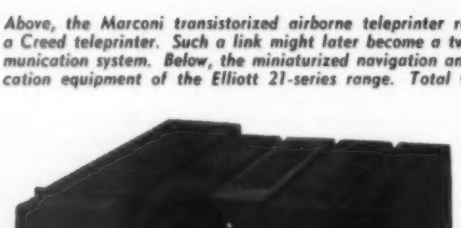
Reliability trends are such that the guaranteed life of a complete unit such as a receiver or transmitter might be so long that it would be economical to discard the whole unit when it first failed.

V.H.F. Communications. Two transmitters and two receivers are the normal complement of current and projected aircraft types. These can be either combined transmitter/receiver or separate units. Modern receivers have 50 kc/s spacing between channels and although the basic principles of V.H.F. communications obviously apply, better interference-suppression, low-noise amplifiers and other improved circuit techniques have all contributed towards enhanced performance. Completely transistorized V.H.F. receivers in course of development should take up about half the room, be significantly lighter and have lower power consumption than their valve-equipped predecessors. But manufacturers seem to think that transistors producing sufficient power for V.H.F. transmitter output stages are unlikely to appear on the market for a considerable time—certainly not at an economical price.

Nevertheless, transmitters incorporating transistors prior to the power stages are well advanced. They utilize ordinary thermionic valves for drive and output and show a decided space-saving. Transmitter valves of the "ceramic" type will be available soon. They will be comparable in size to lower-frequency power transistors and may replace the standard valves in the present transmitter developments. They dissipate a considerable quantity of

The navigator's station in a Comet 4, showing radio equipment for both navigation and communication mounted in the radio racks





Above, the Marconi transistorized airborne teleprinter receiver with a Creed teleprinter. Such a link might later become a two-way communication system. Below, the miniaturized navigation and communication equipment of the Elliott 21-series range. Total width is 1ft

AVIATION ELECTRONICS . . .

heat and one opportunist has already suggested placing them at the top of the transmitter and utilizing the resulting convection currents to cool the other components with high-velocity air.

While older V.H.F. receivers still in use have 100 kc/s channel-spacing, modern equipment uses 50 kc/s spacing so that greater frequency stability is now needed. Earlier equipment was stable to 200 parts in 10^6 but that in current use has reached 100 in 10^6. Equipment now under development provides frequency stability of 25 parts in 10^6. Spurious responses have been greatly reduced and where adjacent-channel interference was 40 db down it is now 100 db down.

The modern V.H.F. receiver has "packaged" selectivity containing specially reliable circuitry to give highly stable and reliable selectivity features and more favourable maintenance requirements.

H.F. Communications. Dual transmitters and receivers are normally carried in airliners and, as is the case with V.H.F. radios, H.F. equipment is being transistorized. Progressive improvements in interference conditions and circuit qualities have also increased overall performance. Telephony in H.F. communications has now virtually replaced telegraphy. It is usual to have a power output of the order of 100 W and as many as 240 channels.

Further use of H.F. communications for international public telephone services in flight has been envisaged for some time. El Al have introduced a service which operates internationally via maritime land stations tied in with telephone and cable circuits.

Single-Sideband H.F. Communications. Broadly speaking, the single-sideband method of H.F. communication makes available a larger number of channels within the allotted band and also provides much more effective use of the R.F. power for a given transmitter output stage and associated equipment. But considerable efforts are being made to solve a number of problems which still stand in the way of full airline use. The optimum communication conditions within the H.F. band are being actively investigated and statistics have already been put forward which suggest an economy by abandoning frequencies below 3 Mc/s.

With the increases in aircraft speed, attention has been drawn to distortion introduced by Doppler effect—a shift in the communication frequency caused by the closing speed between two aircraft or between an aircraft and a ground station. The shift can distort communications sufficiently to interfere with intelligibility, particularly in data-transmission systems. The degree of distortion is proportional to the speed, the effect being to destroy the harmonic relationships between components of a signal by the addition of a constant error to all component frequencies.

Despite these and other difficulties, several manufacturers already have produced advanced prototype S.S.B. equipment and it seems probable that aircraft in approximately VC.10 time-scale will carry it. Retrospective installation in existing aircraft is also possible. A 1 kW airborne H.F. transmitter, smaller and lighter than present units, is probable. Tolerances of frequency stability have been tightened up to one part in 10^6 for S.S.B. as opposed to something in the order of 100 parts in 10^6 in double-sideband equipment. S.S.B. will later be used for data link communications.

Best results in H.F. communication are dependent on many factors, and there are optimum frequencies related to a particular time and geographical position. A service is already provided on North Atlantic routes to advise crews of these optimum frequencies and this process will eventually become automatic.

M.F. Communications. A medium-frequency teleprinter link will be fitted in some Boeing 707s. At present, only meteorological information is transmitted, but it is probable that the intervals between met. messages will in future be used for other purposes such as notification of optimum communication frequencies. M.F. teletype, probably using hybrid radio frequencies, may develop into a two-way system to become a forerunner of the data link in transmitting flight information, position reports and so on.

A.T.C. Transponders. At first sight secondary radar scarcely seems to come under the heading of communications equipment, but the essence of a secondary surveillance radar system for A.T.C. is automatic response from the airborne equipment to an interrogation from the ground station. The coded response identifies the aircraft and shows its bearing and range in relation to the ground station. A not unlimited amount of additional information can be included in the transponder transmissions. An ARINC characteristic for A.T.C. transponders was published some time ago, a British transponder already exists, and a British secondary surveillance radar will soon be evaluated in this country. But the true value of such a system will be appreciated when equipment is installed internationally. The present transponder can provide 64 codes out of a possible total of several thousand and is built into a long ½ ATR box.

Microphones and Telephones. Mention has already been made of the effect on microphones and telephones of lower noise levels in flight decks and cabins, but there are other problems. The American practice has been to demand that all microphones should have the same output level as a carbon microphone at an impedance of 100 Ohms with the result that their intercomm. amplifiers and equipment modulators are of comparatively low gain. In Britain, on the other hand, the equipment has been designed to accept the much lower level to be expected from moving-iron microphones, including the insensitive, noise-cancelling type. These differences make straightforward equipment interchangeability rather difficult. Although the defined levels and impedances for telephones do not agree, this does not seriously affect the situation.

To avoid affecting equipment characteristics, American manufacturers, faced with using lower impedance microphones of higher quality than the carbon type, have attached small transistor preamplifiers to the headset itself, or in the lead, to restore the level to that of a carbon microphone.

To convey the maximum amount of intelligence in voice radio, it is most important to modulate the transmitter as fully as possible. The depth of modulation in the components of a sentence, spoken into the microphone, varies tremendously; and although the mean level might fall in the region of 30 per cent, short-duration peaks would reach 95 to 100 per cent. It was found that by raising the gain of the amplifier and clipping off these higher peaks, the average depth of modulation can be made very much greater without adversely affecting intelligibility. Modern equipment incorporates "speech clipping" which, coupled with automatic control of gain in the speech amplifier, helps to smooth out the differences between microphone users and the variations which can be produced by such factors as head movement.

Because of low noise level on the flight decks of jet aircraft, loudspeakers will probably replace headphones. In such cases, acoustic feedback will be avoided by a novel method which is basically a shift of a few cycles in the speech frequencies.

It remains to emphasize that probably the most significant gain to be expected of transistorization is the improvement in reliability which the transistor and its accompanying components provide. Looking rather further ahead, momentous developments can be expected when future aircraft carry a highly stable frequency source such as a cesium clock for navigational purposes, and designers of communications equipment are already considering its use for a very accurate frequency-reference standard. There is also every likelihood that long-range V.H.F. communications will eventually use earth satellites as dynamic automatic relay stations.

Jet Noise and Society

IT was poetic that at the S.B.A.C. Display, which might be described as the noisiest show on earth, there should have been a demonstration of the social problems caused by jet noise and of the measures engineers are taking to tackle them.

The National Gas Turbine Establishment (N.G.T.E.) of the Ministry of Supply deserves a bouquet for the excellent 22-minute film they showed in a small sound-proof theatre on their stand at Farnborough (see picture). The film, artistically produced and technically plain and straightforward, was supported by high-fidelity stereophonic sound and a well-written commentary.

No particular jet aircraft was cited as a worst offender; rather was it suggested that the high noise level of the first generation of jet airliners was due to the fact that their engines were developed from military experience where jet velocities (the main contributor to noise) were high. The N.G.T.E.'s researches into the noise problem would, it was said, provide the designers of future engines with the information they would need to ensure that every component of the engine made the least possible noise.

After each showing the audience was asked to judge between the noise levels of 16 separate pairs of sounds and to fill in a form accordingly. This was part of the N.G.T.E.'s programme of research into subjective human reactions to noise; it is probable that no comparable programme has been tackled on such a scale.

Jet noise has been very much in the news lately, particularly in London and New York. Weather at both places this summer has been very much of the in-the-garden and open-the-window type; and this, combined with a big increase in jet frequencies, has caused the number of hostile protests to airport authorities—particularly at New York—to become almost too large to handle.

At London two events in particular are worth recording. A committee representing local authorities around L.A.P. recently succeeded in arranging an appointment with the Minister of Transport, following meetings with Ministry officials which had apparently not satisfied the committee members. This meeting was due to have taken place on September 23, but has been postponed until after the election. The committee intended to protest not only about take-off noise but also about jet noise on the approach. (It is significant that at Los Angeles the I.L.S. glide slope has recently been cocked up 9 per cent, from 2½ deg to 3 deg, due to complaints about noisy jet approaches as well as take-offs.)

The other event was the refusal by L.A.P. authorities to allow a delayed Pan American Boeing 707 to take off during the night. The aircraft concerned, a 707 service from Paris bound for New York, had been forced by mechanical trouble to land at London after leaving Paris. The aircraft arrived just after 6 p.m. and though it was ready to take-off again by 1.30 a.m., permission was refused. According to Pan American, many of the passengers spent the night on board the aircraft.

The Battle of New York

These two events typify the problem which jet noise is inflicting both on the public and on the operators themselves. But they are trivial events compared with the problems now confronting the Port of New York Authority. Matters came to a head on September 10 when the P.N.Y.A. resigned from the "community relations" committee comprised of airlines and airport owners (N.A.T.C.C.) which has tried jointly to tackle the noise problem.

The P.N.Y.A. is well known (the airlines would say notorious) for its noise policies. These policies have been consistently pursued since 1952, when public complaints from the residential areas surrounding New York's airports developed into legal action. It is on record that, in the historic month of October 1955, when Pan American placed the first orders for the big jets, the P.N.Y.A. issued the following wise-before-the-event statement:—

"The Port Authority assumes that Pan American would require from the manufacturers specifications which would assure that these aircraft could operate to and from New York International Airport without excessive noise characteristics that would be intolerable to the airport's neighbours. If Pan American has such assurances, the Port Authority, of course, is delighted that this airline has been able to effect this forward step in the progress of air transportation."

It is well known that the P.N.Y.A. issued to jet operators last October a set of requirements for the operations of jets from New York's airports. These were described in *Flight* of October 17, 1958. The requirements still stand, though there has been one modification. In place of the clauses requiring jets to reach an altitude of not less than 1,200ft over residential areas, with power cut-backs precisely specified for each type of jet, the P.N.Y.A. now requires that operations shall be conducted in such a way that a noise level of 112 "perceived noise decibels" (explained in *Flight*, November 7, 1958) is not exceeded over residential areas. This leaves it to the operator, as is proper, to operate his jets in his own way without reference to procedures prescribed by the airport authority.

The film theatre on the National Gas Turbine Establishment's stand at the recent S.B.A.C. Display. In it the Establishment showed its film on jet noise. The article on this page reviews this film and the latest jet noise developments at New York and London

How do the P.N.Y.A. enforce their rules? Every single jet take-off (there were more than 600 in August) is monitored by sound-measurement teams and each aircraft operator is sent a daily report. Every month results are summarized and sent to the residents' associations and to the airlines. In addition, the P.N.Y.A. goes to great lengths to explain to operators in what appears to be a most reasonable way how to adhere to the spirit as well as the letter of the regulations. For example, each carrier is given a simplified runway selection chart according to wind direction and velocity to make it easier for him to select the preferential runway from the noise point of view.

To lay down procedures is, of course, one thing: to ensure that they are obeyed is another. The P.N.Y.A.'s method of enforcement depends to a very large extent on advising operators of their monitored record of conformity. As explained, reports are published for all (including the residents) to see, and the following extract from the most recent circular letter (September 3) shows that the P.N.Y.A. can use strong words when it chooses. Having given Pan American, T.W.A., B.O.A.C. and Aerolineas Argentinas a pat on the back for their relatively good behaviour, the director of the aviation department of the Port Authority said:—

"American Airlines remains as the one jet operator with a completely unacceptable conformance record and no clear signs that it is making any real efforts to protect the airport's neighbours from excessive jet noise. . . . Furthermore, we have had no assurance whatsoever from American that it is disposed to take any positive steps to improve its record.

"In the best interests of all concerned, we will continue to make every effort to persuade those responsible for American Airlines' operations to make a conscientious effort, as other airlines are doing, to conduct their operations in accordance with Port Authority rules and procedures. On the August record of American Airlines, which it is my unpleasant duty to submit to you here, their operations are being conducted with a wilful disregard of the public welfare . . ."

For the record, the Comet 4s of Aerolineas Argentinas and B.O.A.C. conformed 100 per cent in August and Pan American's 707 conformity was 91.8 per cent.

There remains a bigger deterrent, not yet exercised, than public reproof. The U.S. Congress is now so concerned about the noise problem that it is considering giving the Federal Aviation Agency a directive to do something about it. The director of the P.N.Y.A.'s aviation department spent almost the whole of Labor Day (an American national holiday) giving evidence before a Congressional hearing in New York. In the course of this evidence he said:—

"Our General Counsel advises that the Port Authrity has the power to enforce its regulations regarding the use of the airport by jet aircraft. If it became necessary in order to procure compliance to withdraw the permission granted, that would be within the Port Authority's power. However, withdrawing permission to a non-conforming airline to use the airport for any of its jet operations is an extreme sanction. It would prevent a substantial number of operations which do conform and would deny air transportation to the travelling public which does not share any responsibility for violations. Naturally, we would approach the consideration of such withdrawal of permission with great caution."

Meanwhile, local feeling around New York becomes more and more hostile to the jets—stimulating, and no doubt being exacerbated by, prominent "hate" articles in the local newspapers. The M.T.C.A. face nothing like the same onslaught of organized agitation from around London Airport, though the signs are that the already quite disturbing agitation is likely to increase rather than diminish as jet movements increase.

"American Airlines . . . now operate . . . 38 Boeing 707 flights daily, linking eight cities via ten routes."

Jet-age Growing Pains

THE accident to a Lockheed Electra of Braniff Airlines on September 29 was the second disaster to an American turbine airliner in passenger service since the U.S. jet age began a year ago this month. Yet more than 100 707s and Electras are now in service, and the safety and traffic record is here put into perspective.

ALREADY about one million passengers have travelled by Boeing 707, Comet 4 and Lockheed Electra since B.O.A.C. just beat Pan American in introducing the first North Atlantic jet service last October, thus re-introducing the travelling public to the Jet Age—a misleading term from the viewpoint of chronological accuracy, although by now almost indelibly associated with last winter's commencement of 707 and Comet 4 services. It is as yet too early to forecast the long-term effects of this Brave New World in air transport; too early, even, to say for certain whether large-scale introduction of jets will be a blessing or a curse to the industry. But a factual and balanced account of the early months will serve to put sequences of isolated events into some sort of perspective, besides enabling one or two definite conclusions to be drawn.

First of these is the enormous passenger appeal and impressive traffic results of the new generation of turbine-powered airliners. By mid-August American Airlines' Boeing 707-127s and Lockheed Electras had carried more than 500,000 passengers since

By M. J. HARDY

starting services on the same week-end in January, and American claim to have carried more jet and turboprop passengers than any other airline in the world. American now has about 35 Electras and 707s, and the full impact of these new types traffic-wise was shown in A.A.'s July total of no less than 559,854,000 revenue passenger-miles, which for the first time since the war exceeded that of June, traditionally busiest month for the company. American Airlines now operate 70 Electra flights daily, linking 11 cities over 16 different routes, and 38 Boeing 707 flights daily linking eight cities via ten routes. Pan American's Boeing 707-121s made 1,268 transatlantic crossings carrying 148,000 passengers between last October and mid-August. Beginning on October 25, PanAm 707s will fly 24 transatlantic return services per week, to Frankfurt, Amsterdam, Brussels, Hamburg and Copenhagen as well as to London, Paris and Rome. T.W.A. Boeing 707-131s have carried over 250,000 passengers in nearly six months of U.S. domestic operations, and only three flights had been cancelled out of more than 1,900 scheduled.

A recent report by the Federal Aviation Agency on the reliability-record to date has attracted considerable attention. It showed that in five months T.W.A.'s 707s completed 48,380 engine hours with only two precautionary shutdowns in flight. (Not necessarily an engine failure, a shutdown is often a precautionary measure to prevent a failure or damage.) P.A.A.'s jet totalled 64,000 engine hours in a ten-month period with five shutdowns. This record is about "twenty times better than most piston engines," an F.A.A. spokesman said. The study revealed further that P.A.A. and T.W.A. had operated their 707s about nine hours a day, seven days a week, achieving greater utilization than for piston engine aircraft and twice as much daily mileage flown. An F.A.A. engineer attributed the "almost fantastic" reliability of the engines largely to their simplicity. He noted also that, in compiling 112,380 hours of jet operation, neither airline had reported a case of engine fire.

Jet load-factors in the middle or high nineties have been common experiences: National Airlines' first five months of New York - Miami services with 707-121s leased from PanAm have resulted in a sustained load-factor of over 90 per cent. American's Boeing 707 load-factor for the first 60 days of operation was over 95 per cent, and a phenomenal 99.5 per cent during the first 18 days' operation on U.S. transcontinental routes. American introduced the 707 into daily non-stop service between New York and Los Angeles on January 25 (twice-daily as from February 1) and initially the 707-123 interior provided accommodation for 56 first-class and 56 coach passengers, although an increasing demand for first-class travel soon resulted in a revised interior for 68 first-class and 38 coach passengers. But a change back to the original 56-56 interior was made for this summer's vacation period. American's 99.5 per cent load-factor over 18 days—i.e., 3,720 out of 3,751 available seats filled—produced a revenue (including jet surcharge) of no less than $542,600 during this period, assuming an equal division of traffic between first and coach.

An unusual incident occurred recently when an A.A. 707 had to land at Phœnix, Arizona, instead of Los Angeles because of weather conditions at L.A.; it was promptly impounded by the Phœnix police because the airport's insurance did not cover jet landings and take-offs. The 707 was soon released, however, and A.A. had scored another, if unusual, "first." Average load-factor on T.W.A.'s Boeing 707-131 services since these started on March 20 between New York and San Francisco has been 95.9 per cent; the 707-131s are fitted out to seat 46 first-class and 65 coach passengers. And these record load-factors have been attained in spite of the jet surcharge that was I.A.T.A.'s solution to the fare differential issue, and which affects Aerolineas Argentinas and B.O.A.C. Comet operations between Europe and the Americas, as well as PanAm's North Atlantic services.

B.O.A.C.'s achieved load-factors on the London - Tokyo route (which involves sector bookings) are over 74 per cent, and on the North Atlantic about 92 per cent, broken down as shown in Table I.

TABLE I: B.O.A.C. COMET LOAD-FACTORS

Month in 1959	De luxe	First class	Overall
January	67	84	75
February	77	88	82
March	89	89	89
April	94	90	91
May	95	95	94

The Corporation's passenger break-even load factors, which are calculated by deducting from the total operating cost an estimated constant revenue from freight and mail deadload for the particular route, and then dividing by passenger-capacity ton-miles, show that the profitability figure for the Comet 4 lies between 43 and 47 per cent. This varies according to route, seat-arrangement and season, and allows for interest on capital, training and route-proving over the aircraft's life.

Some new Comet services include a weekly "cannon-ball" from London to Hong Kong and Tokyo, which began on August 2, and a twice-weekly service to South America beginning early next year. The London - Hong Kong time is 20½ hours, and the return journey is made in daylight. Pilot training and engineering performance have both been good; further details of the latter and its effect on regularity were given in *Flight* for May 1. Engineering faults have accounted for only 3.75 hr delay per 100 hr scheduled elapsed time against the B.O.A.C. yardstick of 5 per 100 for long

JET-AGE GROWING PAINS . . .

routes with many stages. One point of criticism that has been raised, however, is that passengers sitting over the centre-section fuel tank get cold feet; electrically heated floor matting is being introduced as a remedy.

For Aerolineas Argentinas, Comet break-even load-factor is said by the airline's president, J. J. Güiraldes, to be 50 per cent. Table II compares results per average flight between an Aerolineas DC-6 in 1958 and a Comet in 1959; the almost fourfold increase in revenue on the New York - Buenos Aires route is worth noting.

TABLE II: AEROLINEAS DC-6 AND COMET TRAFFIC

	DC-6 (May-June '58)	Comet 4 (May-June '59)	Percentage gain
European services:			
Passengers carried	44	58	31
Revenue (pesos)	585,130	1,240,180	111
Passenger-km flown	385,790	527,590	36
Seat-km flown	615,150	761,980	23
Seat load-factors (per cent)	62.71	69.24	6.53
New York services:			
Passengers carried	32	59	84
Revenue (pesos)	257,531	1,250,149	385
Passenger-km	253,593	468,304	84
Seat-km	515,107	546,672	6
Seat load-factors (per cent)	49.23	85.66	36.43
Santiago de Chile services:	(Apr-June '58)	(Apr-June '59)	
Passengers carried	29	43	48
Revenue	41,184	83,821	103
Passenger-km	32,886	47,925	45
Seat-km	60,156	75,570	25
Seat load-factors (per cent)	54.67	63.42	8.75

Labour Disputes. Introduction of jet and turboprop travel by U.S. domestic carriers at the turn of 1958 was marred by a series of costly strikes which had the effect of shrinking the 1958 profits of these carriers to about $30m, i.e., to the level of eight years previously, in spite of a threefold increase in business over 1950. By December 31, 1958, Eastern, T.W.A. and American had respectively lost 38 days, 18 days and 12 days of operation through labour troubles and had suffered revenue losses of some $23m, $12m and $9m. Pan American, too, was suffering because its regular pilots were not flying 707s in the absence of a union contract with ALPA (the Air Line Pilots Association), and the limited number of supervisory pilots available for 707 services led to under-utilization of the Boeing jets during the initial months of operation. From October 26 to the last day of 1958, PanAm's 707 utilization worked out at an average of 6 hr 54 min a day, while National achieved 6 hr 42 min daily. Even so, PanAm's 707s carried 12,168 passengers during the first six weeks of operations, resulting in a load factor of 94.2 per cent.

But Eastern was worse off in that it had eight newly-delivered 70-passenger Electras, which were to have commenced services on December 1, sitting on the ground idle; Eastern's mechanics and flight engineers were on strike and the powerful International Brotherhood of Teamsters had promised "moral and financial help" to the striking FEIA (Flight Engineers International Association). Teamster drivers were pledged not to deliver avgas across FEIA picket lines, and in one instance refused to deliver kerosine to Eastern for Electras at Newark. American Airlines sued ALPA for $90,000 a day retroactive to November 23, when the union threatened to strike, on the grounds that the mere threat of a pilots' strike was causing a loss of revenue. After the walk-out A.A. took its case to the public by means of full-page advertisements in as many as 25 newspapers, denouncing ALPA's attitude as "selfish and arrogant"; perhaps not even the B.O.A.C. strike just after Comet 4 services began aroused such feelings.

But, unlike Eastern, A.A. was in the end able to begin Electra services on the planned date—January 23—between New York and Chicago at an initial frequency of six round trips daily; A.A.'s Electras accommodate 68 first-class passengers in four-abreast rows. Eleven days later an A.A. Electra crashed into New York's East River while making a night landing in fog and rain at La Guardia; this resulted in a change of altimeter being made in the 20 Electras delivered to American and Eastern. Earlier that same day a PanAm 707 *en route* from Paris to New York suffered an autopilot failure which resulted in a steep dive from 35,000ft to 6,000ft.

The crew complement issue which was such a major factor in these strikes was solved by American, and shortly afterwards by Eastern, who both agreed to a crew of three pilots and one flight engineer for their big jets, an arrangement which it is estimated will cost American $4m a year once all their jets are in service. Eastern resumed operations on January 5 after losing $28m in revenue, and *The Miami News* estimated that Eastern's grounding had caused a loss of $16.2m to Greater Miami's economy. PanAm also reached agreement with ALPA on a four-man jet crew with effect from February 4. PanAm's fourth man will act as navigator, besides being a pilot; the duties of American's extra jet-crew member—and presumably those of other U.S. domestic carriers—will have a rather different emphasis. They will consist mainly of communications and record-keeping during flight—which will certainly be no sinecure in the jet-crowded American skies of the next decade and which can no longer, in A.A.'s opinion, be adequately handled by two pilots and a flight engineer. Further problems in jet-age crewing arise from the F.A.A. proposal that pilots of 55 and over would be precluded from taking type ratings on jet aircraft (see *Flight* for September 11), and B.O.A.C. pilots' desire for a substantial pay rise for flying the Corporation's 707s.

Technical Troubles. Meanwhile, during the first month of Electra operations it was found that, at high speed and low altitude, fuselage vibration in the plane of the airscrew discs caused an increase in noise level that caused passengers seated forward of the airscrews to complain. This "bug" occurred only at low angles of attack and at a particular inclination of airflow, and no question of safety was involved, but curing it involved a fairly drastic modification, namely, tilting the engine nacelles to give a three-degree upward inclination to the thrust-lines. One of American's Electras, N6110A *Flagship St. Louis*, was taken off the production line and instrumented for vibration tests, which were later followed by flight tests. This modification can apparently be incorporated on Electras already in service by exchanging engines for new quick-change nacelles suitably realigned.

In order to damp vibration of the Allison 501-D13 it was first necessary to analyse its sources, of which there were three principal ones: the airscrew turning at 1,020 r.p.m., the compressor/turbine combination turning at a constant speed of 13,820 r.p.m., and turbulence from the jet efflux. The 501 has a much higher power-to-weight ratio (2.14) than most piston engines, and its higher power and lower frontal area demanded a stiffer mounting, whereas the engine's lower weight demanded a softer one. The answer to this problem was provided by the Lord Manufacturing Co. of Erie, Pa., who designed a three-point suspension system of bonded rubber mountings in which even under extreme shock-load conditions there is no metal contact; the rear mounting acts as a two-directional link for fore-and-aft thermal expansion, besides resisting the pitching moments created by gyroscopic action of the propeller and compressor/turbine combination. This rear mounting incorporates an integral cooling system, because skin temperature at this point is nearly 600 deg F.

The first production Electra incorporating tilted-up nacelles was VH-TLA, delivered to Trans-Australia Airlines on June 24, and this remedy, together with a reduction of propeller stresses achieved by changing the blade angles, has materially improved vibration and noise in the forward part of the fuselage. Nevertheless, this cure is not a cheap one: Mr. Frank Judd, Northwest's vice-president operations, has quoted its cost as $240,000 per aircraft, to be borne by Lockheed. This sum is over ten per cent of the price of a complete Electra—those of Eastern cost about $2.1m each, including some $50,000 worth of changes requested by Eastern—and it is possible that Lockheed may have to pass the cost of tilt-up modifications on to future Electra customers.

Other teething troubles experienced in the early days of Electra operation included two cases of partial failure of the nosewheel oleo leg (one damaging all four airscrews when the aircraft veered off the runway) and several minor but annoying electrical malfunctions such as false engine-fire warnings. Several Electras have lost cabin pressure in flight, and a dozen out of 14 aircraft in one fleet were found to have cracks in the cabin pressurization duct. Cracking of the wing-skin, a more serious fault, was also discovered and put right in its early stages.

Allison 501-D13 overhaul time has already reached 800 hours in American's Electras and 1,000 hours in Eastern's—the longest time yet authorized for a U.S civil gas turbine—while the corres-

"Allison 501-D13 overhaul time has already reached 800 hours in American's Electras and 1,000 hours in Eastern's." One of the latter is seen in this picture

JET-AGE GROWING PAINS . . .

ponding figure for Pratt & Whitney JT3C-6s in PanAm 707s is also 1,000 hours. Apart from the loss of an engine pod during a training flight over France, PanAm had suffered five premature JT3C-6 removals by early March, the causes of which were not related to one another.

An interesting point revealed by M. G. ("Dan") Beard, American Airlines' assistant vice-president equipment research, in a paper to the Society of Automotive Engineers, is that at high speeds on the ground the 707 must actually be "flown," especially laterally. This is especially true in crosswinds, since a mere 7 or 8 deg of lateral roll can scrape the outer engine pod on the runway.

One Boeing 707 engine failure was caused by a burnt shaft bearing arising from a blade failure in the third-stage turbine; the resulting vibration cracked a strut in the nozzle, severing an oil line running through it. The 707-120's water injection system has also been a source of trouble. In one instance all four engines flamed out when full take-off power was applied, because the water-valve motor, which had been malfunctioning on the previous flight, had been wrongly set by a ground engineer to operate at 70 per cent power instead of the prescribed 95 per cent, with the result that combustion was doused by excess water. In another case, two engines flamed out after take-off when the de-icer units were turned on. This was because a leaking water seal had allowed about a gallon of water to accumulate in an engine nose-bullet, so that when compressor bleed air for the de-icers was applied the water was injected into the engines. As a result of this incident, Pratt & Whitney recommended that the de-icers be turned on one at a time until an improved seal could be developed, and the igniter plugs kept on until after the aircraft had reached 5,000ft, instead of being employed only during starting; this may have resulted in a reduction of igniter-plug life to 500 hours.

A modification was also necessary to rectify an 8in hairline crack found in the skin of a PanAm 707-121 near the wing root; this was discovered in the secondary structure when the aircraft was undergoing its first 200 hr inspection. The 75in-long wing-splice plate in which this crack was found was replaced by three similar plates each about 25in long.

Hydraulic Malfunctioning

In the first five months of 707 operation five instances of hydraulic malfunctioning were reported; in one case a 707 lost all hydraulic pressure and damaged six tyres in landing. Hydraulic pump or reservoir failures resulting from high system-pressures were the principal causes. Cases of brake overheating which occurred, mostly on crew training flights, have suggested the need for some type of coolant such as a water heat-exchanger.

A crop of further incidents in July and August involved undercarriage troubles and resulted in two requests in Congress that the 707 be grounded. A PanAm 707-121 taking off from Idlewild for London on July 11 lost the rear pair of wheels from its starboard bogie, but landed safely after burning off fuel for four hours. There were also several occasions when 707 undercarriages had to be lowered manually or by gravity, implying that both the main hydraulic system and its electrically-driven back-up had malfunctioned. There were two main reasons for these undercarriage troubles: fatigue in the bogie beam following failures in the bolts which attach a damper to the beam and to the landing gear strut; and pressure-rise in the hydraulic system, possibly caused by a choked filter and resulting in pump or seal failure. The F.A.A. have recommended that landing gear beams be inspected every 60 hours and replaced if impact dents larger than 0.005in are found, and that certain hydraulic pumps should be replaced or be fitted with a by-pass valve.

On August 15 an American Airlines 707-123 crashed on Long Island while on a crew training flight; it seems that the aircraft had been making a left turn when its right wing suddenly dropped and it turned right over on its back before its nose struck the ground. It is believed that the starboard engines were stopped when the accident occurred. Eleven days later a Continental Air Lines 707-124 lost part of a leading-edge flap, measuring about 10in wide × 18in long, shortly after taking off on a crew training flight. This flap had already been redesigned by Boeing, and the modified version is now fitted to all Continental's 707s. A similar incident occurred on September 8 when part of a flap—it is not clear whether it was a leading-edge or a trailing-edge one—fell off an American Airlines 707-123 over Los Angeles and knocked a woman unconscious. This piece of flap measured 3ft × 1ft, and another part of the flap, 8ft long, was found to be missing on landing.

Higher Costs. It is not, perhaps, surprising that the first few months' experience of 707 and Electra operations indicate that these new airliners are costing U.S. airlines almost double the figures originally cited in the brochures, and may very well need their high load-factors and considerable passenger appeal to make their operations—at any rate the first year's—profitable. This is illustrated in cost data for the first quarter of 1959 filed with the C.A.B. and quoted in the June issue of *Airlift*. Particularly noteworthy is the effect that air traffic control considerations have had on Boeing 707 speeds (Table III).

Comet 4 "engineering faults have accounted for only 3.75 hr delay per 100 hr scheduled elapsed time against the B.O.A.C. yardstick of 5 per 100 for long routes with many stages"

TABLE III: DIRECT COSTS PER REVENUE HOUR

	American	National	PanAm
Boeing 707:			
Flying Operations ($)	475	351	562
Maintenance ($)	467	—	391
Depreciation ($)	458	—	279
Rentals ($)	—	876	—
Total ($)	1,400	1,227	1,232
Direct costs per seat-mile (cents)	2.74	2.47	2.35
Block speed (m.p.h.)	477	447	477
	American	**Eastern**	
Electra:			
Flying operations ($)	199	217	—
Maintenance ($)	261	126	—
Depreciation ($)	167	166	—
Rentals ($)	148	—	—
Total ($)	775	509	—
Direct costs per seat-mile (cents)	3.43	2.20	—
Block speed (m.p.h.)	332	333	—

It is a sobering thought that not even 90-plus jet load-factors made a profit for American Airlines; A.A. lost $1,977,000 in the first quarter of 1959, which was offset by $1,129,000 from the sale of property. Admittedly, labour troubles take a full share of blame for A.A.'s being in the red, but as more and more U.S. airlines introduce jet and turboprop equipment the novelty of jet travel will tend to wear off; price competition in the shape of reduced fares will come increasingly to the fore as quality competition is played out to its limits. As Mr. Robert Buck, special adviser to T.W.A., observed more than a year ago: "It is a thin piece of ice we skate along between technological improvement and bankruptcy."

But apart from the obvious lesson that troubles are not endemic to British aircraft, the 707's early months of airline service should have completely disproved the fallacy, so widely accepted in this country, that military backing is an open sesame to trouble-free commercial operation and for that reason is desirable, if not actually essential, for new British airliners. In addition to the indirect benefits of large-scale B-47 and B-52 experience and production, nearly 200 KC-135s had been built when PanAm started 707 services last October; probably no other airliner has ever had the benefit of such mammoth military backing. Moreover, total military operational flying time with the KC-135 had exceeded 115,000 hr by the beginning of December 1958, while up to July 31 of this year Comet variants from the Mk 1 to the Mk 4 had totalled some 72,800 hr of test, airline and military transport flying; in terms of hours flown, Boeing can now claim at least twice as much jet transport experience as de Havilland. Again, the Allison 501 has not had a trouble-free commercial career, in spite of "Operation Hourglass," in which 1,000 hours' flight time were accumulated under commercial conditions some 18 months ago in a Convair YC-131C leased by Allison from the U.S.A.F.; there was also the benefit of considerable experience with the 501's military predecessor, the Allison T56, in the C-130A Hercules. The lesson is plain: America's vast resources, apparent technical invincibility and all-powerful salesmanship should not debilitate British turbine airliner efforts in future by fostering an attitude of "We can't afford it, because there is no foreseeable military application for it."

The Frontiers of Science

POINTS FROM A LOS ANGELES SYMPOSIUM

By DON ADAMS

OPENING his address to the "Frontiers of Science and Engineering" symposium held in Los Angeles on September 15-16, Dr. Milton Clauser of the Space Technology Laboratories remarked that man's ability to forecast the future was limited. More often than not we under-estimated actual rates of progress. Had a number of people been asked ten years ago to speculate on subsequent developments, few if any would have anticipated the startling advances of the past decade. Yet forecasting the future was exactly what was requested of the renowned scientists and engineers brought together to speak at this particular symposium.

Co-sponsors of the widely heralded and well-attended meeting were the University of California and the Institute of the Aeronautical Sciences. The symposium was divided into four sessions, devoted respectively to astronautics; physics; vehicles and operations; and technology. During each session the various specialists spoke of work in their particular fields, first summarizing the current state of knowledge and then endeavouring to predict the advances which might take place in the next ten years. As several of the speakers observed, the average person is so accustomed to reading newspaper and magazine accounts of the wonders that lie ahead that a scientist's guess at the future might sound unduly conservative. The speeches indeed reflected conservatism; even so, the listeners could not help but be impressed.

Brief summaries of the speeches which were of particular interest in the fields of aircraft and space vehicles are given below under appropriate headings.

Astronautics. After an introductory speech by Clark Millikan of the California Institute of Technology, Sidney Chapman, of the staff of the High Altitude Observatory at the University of Colorado (and well known in England), spoke on the subject of *Space Environment*. He made a plea for the widest possible use, in satellites, of instruments to investigate our environment. If called upon to cite the one instrument which would produce the most needed information he would name the spectroscope, with which ultra-violet radiation could be observed. In summation, he opined that all of the planets in our solar system would be ultimately subjected to manned exploration; however, journeys beyond the outer planets, even to the nearest star, were "incomprehensible."

Speaking on the subject of *Astromechanics*, Samuel Herrick of the University of California felt that the use of the Moon as an accelerating device* for spaceflight was impractical. Much more had to be known about the Earth's atmosphere, magnetic and gravitational fields before spot landings on the Moon could be attempted. Existing uncertainties about the Earth's gravitational field were alone sufficient to produce landing errors of 100 miles on the Moon. Resupplying of manned Lunar bases would hence be difficult until more precise measurements of Earth gravity were made. The use of low-thrust devices (i.e., ion engines) for space travel would produce severe navigational problems because of the same uncertainties.

Highlight of the first morning's session was a talk on *Biomedicine* by Brig-Gen. (Ret) A. Schwichtenberg of the Lovelace Foundation. He emphasized the importance to all mankind of experiments now being conducted in support of the "Man in Space" programme. New instrumentation and investigative techniques, particularly those which related to men under physical and mental strains, should prove of immeasurable value in the future; but he regretted that even further studies were not being made. Considerably more money was spent on vehicle development than on tests of man under simulated space conditions. Of especial interest would be tests of man under combined heat, acceleration and vibration environments. It was known that the presence of heat reduced man's ability to withstand accelerations, and vibrations superimposed upon accelerations were also of critical importance and should be investigated. Perhaps the supersonic track at Holloman A.F.B. could be used for testing under combined environmental conditions.

The speaker noted that during a test at NADC, Johnsville, a human subject had withstood accelerations of 2g for a period of 24 hours without harmful effect. These conditions, Gen. Schwichtenberg stated, were "equivalent" to travelling 45,000,000 miles (one-half the distance to the Sun). Gen. Schwichtenberg felt that much had yet to be learned about radiation protection.

The speaker's forecasts for the future were that tests of the Project Mercury type would be routine by 1970. Manned Moon-landings would have already taken place or would shortly be completed. Extended space flights beyond the Moon would be near realization. He foresaw the greatest-ever increase in knowledge in the next decade. Closed ecological systems would have been developed by 1970, and a few space "accidents" would have taught us the need for reliability. The possibility of placing space travellers in a state of suspended animation (by cooling) could also be predicted.

Physics. Afternoon papers of the first day were devoted to speeches by James Moyer of General Electric Co. (on *Free Radicals*), by J. Krumhansl, editor of the *Journal of Applied Physics* (on *Solid-state Physics*), and by J. Pellam of C.I.T. (on *Cryogenics*).

The use of free radicals as a source of propulsive power was improbable, according to Mr. Moyer. Whereas concentrations of 10 per cent (of hydrogen) were necessary to produce worthwhile specific impulses (800 to 1,000 sec), there might be a fundamental limitation to achieving concentrations beyond the 0.1 to 1 per cent already produced in the laboratory. Recombination ramjets, which utilized free radicals from the upper atmosphere, were impractical.

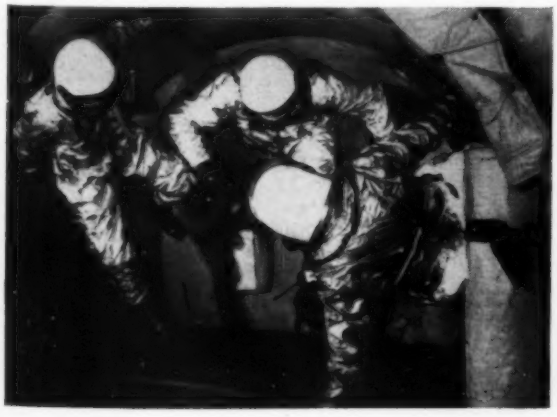
Vehicles and Operations. In his paper on *Operations Research*, Dr. George Kimball of the Arthur D. Little Co. traced the beginnings of his field from the work performed by Prof. P. M. S. Blackett in England (during Battle of Britain days) in analyzing the use of radar. These British efforts inspired the U.S. to participate in operational research work. The speaker defined such research as "beginning where engineering left off." It was a study of the process of integrating men and machines into an operational system, with optimum effectiveness.

Contrary to popular opinion, operational analysis was not a branch of mathematics. This misconception arose because much of the results of studies were still held under a cloak of military or industrial security. Consequently, virtually all published works on the subject dealt with the unclassified mathematical aspects of the problem. Dr. Kimball felt that since many of the early operational research studies were now over ten years old there was no longer a security issue and that a number of studies would soon be revealed. The field would receive new impetus when students could subsequently examine factual case-histories.

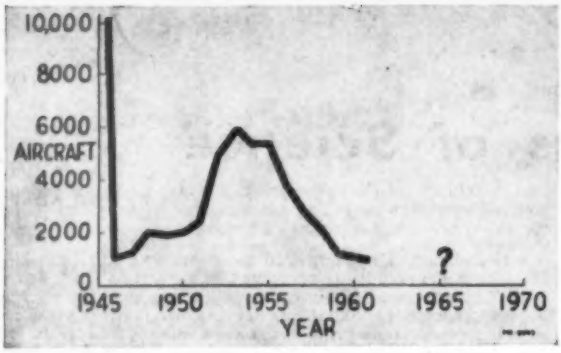
Operational research work in the field of space was difficult to perform, because the data required as inputs were tenuous in nature.

George Schairer, vice-president of Boeing Airplane Company, spoke next, on the subject of *Transports*. He foresaw the introduction of supersonic types within a short time; but in regard to the attendant noise problem, he said: "I will not forecast whether they will fly over land." In addition to a substantial increase of long-haul traffic, predicted Mr. Schairer, there would be a dramatic increase in short-haul trade. The aeroplanes of the future would be quite different from existing types. Really long-range vehicles

*By passing behind the Moon near lunar escape velocities, it is theoretically possible to realize an accelerative impulse of 500 feet per second.



"Man in Space" experiments were discussed by Brig-Gen. Schwichtenberg at the symposium. This photograph shows Project Mercury astronauts experiencing short-period zero gravity in a Convair C-131B aircraft flown in a Keplerian trajectory. These zero-gravity studies are conducted by the Aero Medical Laboratory of Wright Air Development Center, Dayton, Ohio



In Mr. Heinemann's paper the graph (left) emphasizes how procurement of American combat aircraft is declining. Above is his conception of a "slow" intercepter, carrying air-to-air missiles with great range and high supersonic speed

The Frontiers of Science . . .

could be forecast for the future. Elimination of ground-support equipment was a goal, and there was a good prospect for improved seating in economy- and tourist-class arrangements. Rocket-powered transports were way off in the distant future.

A paper on *Military Aircraft*, by E. Heinemann of Douglas, followed. Top speeds of 2,000 kt for typical military aircraft could be forecast for 1970; and cruise speeds of M3.5 would be commonplace during that time era. Turboramjets would be used for M5.0 flight, and the cost of the structure of these vehicles (assumed to be structural steel sandwich) would be ninety times that of conventional Dural structures. The weight of fighter aircraft would approach 140,000 lb in 1970, while attack aircraft would gross 100,000 lb. No decrease in s.f.c. could be foreseen in the next decade; it was expected to remain at 1.0, but engine specific weight was expected to drop to 0.2. Optimum engine specific weight appeared to occur in a thrust range of 4,000 to 5,000 lb, and engines in this size-category were hence of "real interest" for VTO operations.

By 1970 the cockpit, probably integrated in an escape capsule, would have but two primary flight instruments, a reduction from the 13 instruments in 1960 aircraft. A hundredfold increase in avionics components could be foreseen for 1970 in comparison with 1945, and reliability of sub-systems would have increased by a factor of three during that period. The cost of fighter aircraft would have doubled between 1955 and 1960, and a reappraisal of the entire fighter situation was in order. "Common airframes" for many purposes could be foreseen. The development cycle for wholly new aircraft was now ten years from conception to deployment. The cycle for second-generation aircraft was 5½ years, while even simple reorders of production aircraft required 2½ years lead time for fulfilment.

The lecturer showed several colour slides depicting the Douglas company's conception of future aircraft. Fighters were seen to be moderately swept—and probably subsonic—turbojet-powered types, and close support aircraft closely resembled the fighter. The A.E.W. aircraft of the future was a four-turboprop land-based aeroplane, while the A.S.W. aircraft was a small-turbojet-powered straight-wing machine. The logistics aircraft had two turboprops and a tilt wing. The reconnaissance aeroplane was a delta-wing canard type with an under-fuselage inlet. This last field was probably the only application for true high-speed aircraft.

Space Vehicles was the topic discussed by Krafft Ehricke of Convair. Bigger, faster and heavier vehicles were foreseen for the future. Higher specific impulses and thrusts were needed to do away with the unattractive requirement for assembling vehicles in Earth orbit.

Controlled-fusion propulsion was a hope for the future. Ion engines, with 10^{-2}g acceleration seemed more feasible than plasma-engine devices. Solar energy was impractical as a propulsive source for journeys beyond Mars. Underground, or "coupled" launchings (from tubes) were not feasible for chemically powered vehicles, although such measures might be adopted for fusion-powered craft. The author could not foresee controlled nuclear explosions as a power source for space vehicles.

Technology. The last afternoon was occupied by papers by C. S. Draper of M.I.T. (on *Instrumentation and Inertial Systems*), by Roderick Scott of Perkin Elmer (on *Photography*), and by Simon Ramo of Thompson Ramo Woolridge (on *Electronics*). Following these papers was the feature of the symposium—a speech by Dr. Edward Teller of the Lawrence Radiation Laboratory at the University of California on *Nuclear Power*. Two great problems remained in fission reactor design. These were: how to handle great temperatures; and how to extract uranium cheaply from low-concentration materials. Controlled-fusion propulsion was unlikely in the immediate future. Dr. Teller derided controlled (and continuous) nuclear explosions as a power source for space vehicles. He called these "BATO"—bomb-assisted take-offs. Nuclear rockets, offering increases in specific impulse—a factor of 2 to 3 was cited—would be developed within ten years. Ion propulsion might or might not prove worthwhile. Controlled thermonuclear propulsion (fusion) devices were promising, but probably would not be available until the 21st century. Approximately 5 per cent of the speed of light could be realized with a single-stage, thermonuclear-powered vehicle having a mass ratio of 1. Higher speeds might be achieved with multi-stage units of the same power, but the problems of accomplishing such a proposal were significant.

Dr. Teller believed it would be feasible to explore our planetary system in this century; beyond that, "we are in trouble." With regard to life on other heavenly bodies—there was no question but that there was—and the related question of why such other beings had not yet visited our planet, the speaker recounted a conversation he held some years ago with the late Enrico Fermi. The discussion was called "Where is everybody?" It was agreed that we were in a "god-forsaken" location in our galaxy (roughly two-thirds of the distance out from the centre), and the inner inhabitants simply had not bothered to venture out to the system in which we lived.

Far off in the distant future, said Dr. Teller, there was the possibility of propulsion sources superior to thermonuclear reactions. One of these might consist of the "annihilation" of anti-matter and matter. Journeys to Alpha Centauri (one of the nearest stars) would have to await the 23rd century.

Krafft Ehricke, who spoke on space vehicles at the Los Angeles meeting, is seen with Convair vice-president J. R. Dempsey (left) holding a model of the second-stage Centaur. Right, future ion-propelled space vehicle proposed recently by Lockheed would be powered by nuclear reactor towed at end of one-mile coaxial cable

Closely "escorted" by three Hunter F.6s of No. 111 Sqn.—in an unfamiliar straight and level role—is the Turbulent G-APNZ which bears the Royal arms and is flown by the Duke of Edinburgh's equerry-in-waiting, S/L. John Severne

SERVICE AVIATION

Royal Air Forces and Naval Flying News

Victors in Iran

TWO Victors of R.A.F. Bomber Command are visiting Teheran next week to take part in a flying demonstration on October 18 marking Imperial Iranian Air Force Day. The detachment is to be commanded by Air Marshal Sir Kenneth Cross, A.O.C-in-C. Bomber Command, and will include a transport aircraft. The Victors are due to arrive in Teheran next Friday (October 16) and the following day will be on show at Mehrabad airport.

Hastings V-Force Trainer

MENTIONED by Sir Frederick Handley Page in the recently published Handley Page annual report [*Flight*, September 4], the first of a small number of Hastings aircraft converted for the training of V-force bomber crews is soon to fly. Designated T. Mk 5, this new-look version of the familiar transport is distinguished externally by an under-fuselage radome approximately 12ft long and 7ft wide, the front of it level with the wing trailing-edge. The cabin has been fitted out to permit the training of three crews on each flight. Performance will be much the same as for the Hastings Met. Mk 1, from which the training aircraft has been adapted.

Arabian Peninsula Command

ASSUMPTION by Air Chief Marshal Sir Hubert Patch on Thursday last week of his new appointment as Commander-in-Chief, British Forces Arabian Peninsula (*Flight*, August 28), marks the inauguration of a unified command system at Aden. The new C-in-C. has under him three subordinate single-Service commanders of major-general or equivalent rank, this re-organization being designed to increase the military effectiveness of the Command by relieving the C-in-C. of the burden of day-to-day administrative work.

Air Chief Marshal Patch has been Air Member for Personnel since April 1, when he was promoted to his present rank. He was Commander-in-Chief, M.E.A.F., for the previous three years. A.V-M. M. L. Heath, his predecessor at Aden (as Commander, British Forces, Arabian Peninsula), is to be Commandant of the R.A.F. Staff College from next month.

IN BRIEF

Admiral Sir Charles Lambe, Chief of Naval Staff, sent a letter to the Soviet Ambassador in London expressing gratitude to the crew of the Russian trawler who picked up the three airmen in the Skyraider from H.M.S. *Victorious* who had been forced to ditch their aircraft in the North Sea.

* * *

Admiralty have announced that the R.N. air station at Brawdy, Pembrokeshire, is to stay in commission until at least 1962.

* * *

The Lawrence Minot Trophy, premier award in Bomber Command's annual bombing competition, has this year been won by No. 617 Sqn.

* * *

R.A.F. West Malling was "at home" to about 600 members of the Royal Observer Corps (Metropolitan Area) last Saturday, and R.A.F. Stradishall is to be similarly "at home" to local R.O.C. members on October 18.

* * *

Command of R.A.F. Spitalgate was taken over last month by G/O. Janet Bannatyne, who thus became the second woman to command a Royal Air Force station, the other being G/O. Hill at Hawkinge. Spitalgate, near Grantham, is a centre for training R.A.F. and W.R.A.F. officers in Service accountancy and administration; next year the W.R.A.F. School of Recruit Training is moving there from Wilmslow in Cheshire.

* * *

Badges of No. 3 Group and of No. 49 Sqn. were presented to the officers' mess at R.A.A.F. Amberley, Queensland, to mark the recent visit by Valiants of Bomber Command during the state's centenary celebrations. These presentations were made by A.V-M. M. H. Dwyer, the A.O.C. No. 3 Group, and W/C. R. Payne, who commands No. 49 Sqn., from which the Valiants were drawn. The R.A.F. were also represented (this page, September 18) by a Comet, Britannia and Hastings of Transport Command and a Beverley from F.E.A.F.

* * *

Seventy-five thousand people visited the R.A.F. Battle of Britain exhibition on Horse Guards Parade between September 14 and 20.

* * *

A full flight simulator has been ordered by the R.C.A.F. for the military transport version of the Canadair CL-44D, designated CC-106. A contract worth approximately $1m (Canadian) has been placed with Redifon Ltd. in association with Redifon-Canada.

* * *

Cpl. D. L. Street, an air wireless fitter who recently returned to the U.K. from Malaya, has been awarded £20 for an item of equipment for testing radios in the crew-seat positions in aircraft. The award was made while he was stationed at Seletar by the C-in-C. F.E.A.F., Air Chief Marshal the Earl of Bandon.

* * *

Sgt. Pat Cunningham, an air signaller with the Air Supply Force at Kuala Lumpur, recently completed his 400th supply-dropping sortie over the Malayan jungle. A tankard donated by his colleagues to mark the occasion was presented to him recently by the C.A.S.-designate, Air Chief Marshal Sir Thomas Pike, during the latter's visit to F.E.A.F. units.

* * *

No. 11F (Brooklands) Sqn., A.T.C., is holding an all-ranks reunion on October 29 to celebrate the 21st anniversary of its formation. The squadron is anxious to contact ex-members, particularly those of pre-1947 vintage. Further information may be obtained from the commanding officer, F/L. M. W. B. May, Ashburton House, Send, Woking, Surrey.

Britannia layout for carrying 53 stretcher-cases being explained to R.A.F. nursing sisters by S/L. C. A. Bentley, senior medical officer at Lyneham, where an aero-medical centre has been established. On the left of the group is the Air Commandant of Princess Mary's R.A.F. Nursing Service, Air Cdt. A. Lowrey

Correspondence

The Editor of "Flight" is not necessarily in agreement with the views expressed by correspondents in these columns. Names and addresses of writers, not for publication in detail, must in all cases accompany letters.

Double-flow Engines

ON page 263 of your issue of September 18, under the heading of "Powerplants" and referring to the growing trend towards by-pass engines, you say: "The manner in which this has come about is well known: after initial exploration by such companies as Turboméca and Metrovick, Rolls-Royce established the first standard with the Conway . . ."

Evidently, the true facts are not well known—certainly not to the member of your staff who wrote these words, otherwise it would be almost incredible that he could fail to mention Power Jets Ltd. in this connection.

Power Jets were working on various ducted-fan schemes from 1942 onwards and the first of the many patents relating to this class of engine is dated March 1936. The status of Power Jets as the true pioneers would have been clear for all to see by about 1947 if the active projects had not been stifled by the nationalization of the company and its subsequent conversion into the N.G.T.E.

In case your writer is not convinced by these remarks, may I point out that the Conway is made under licence from Power Jets (R. & D.) Ltd.—the Government company which owns all my patents relating to aircraft gas turbines. The same applies to the General Electric CJ-805-21, according to a letter recently received from Mr. T. G. Hicks, managing director of Power Jets.

Exeter, Devon. FRANK WHITTLE.

[The writer was well aware that Power Jets Ltd. were the original patentees, but in this particular review was confining his attention to what might be called "hardware." This seems to be an occasion, however, to acknowledge the astonishing foresight of Sir Frank and his associates in pioneering what is now becoming the standard form of turbojet for transport work, as well as for several military applications.—Ed.]

Passengers and Piers

I WAS very interested to read your comments on London Airport's new long-haul terminal (*Flight*, August 28). We in B.E.A. remain as convinced that the pier layout for airport terminal buildings is the right answer, as we were when we first advocated this system both in the planning of Gatwick and on the Millbourn Committee. Our experience at Gatwick has confirmed our belief that piers are essential for handling passengers expeditiously, for improving punctuality and for reducing the time spent by aircraft on the ground.

We know of no single passenger complaint about Gatwick's pier, which has materially assisted us in achieving a consistent 90 per cent on-time performance compared with London Airport's average of 55 per cent. A contributory factor in the latter case is the airport layout involving coaching to the outer stands. Apart from this added and time-wasting complication, there is no protection which a coach can give to passengers against noise and blast that cannot be provided in a conventional pier. The alternative of subways linking the terminal with diamond-shaped aircraft parking stands—admittedly easier from an aircraft manœuvring point of view—creates serious inconvenience to passengers, who will be fatigued by unnecessary changes of level and depressed by long walks in gloomy tunnels. The airlines do not like this solution for these reasons and also because their airport costs would inevitably be substantially increased to pay for the higher capital and maintenance costs.

I agree with you that it is surprising that the new terminal building is to be built initially without fingers, in view of the fact that the pier system was one of the main recommendations of the Millbourn Committee.

Ruislip, Mddx. E. P. WHITFIELD,
Traffic Director, British European Airways.

A Comet in the Commonwealth

HERE is a further report on the doings of the Comet 4 in darkest Australia. Today (September 19) a series of demonstration flights were arranged, two in the morning and two in the afternoon. These took the Comet 4 over Sydney to Wollongong, 52 miles to the south in the Illawarra district and one of three large steelworks centres. The flights also included a sweep over the Blue Mountains to the west and north almost to Newcastle, N.S.W.

Once more there was a nigger in the woodpile. Earlier in the week all papers here carried a large and impressive B.O.A.C. advertisement announcing the arrival of the Comets on the Sydney - London service. However, nothing was said in this advertisement about the public being able to see the Comet 4 at Mascot (open to public inspection on a Friday, if you please, when most of Sydney is working). Nor was any mention made of the proposed demonstration flights today. Only one paper today, the Sydney *Daily Telegraph*, carried a note about these flights and this was tucked away on the back pages, in so minute a format that few could even have noticed it. The other paper, the *Sydney Morning Herald*, had not a word about these flights.

Worse still, the minute announcement which *did* appear in the *Telegraph* did not enlighten the public as to the times at which the Comet was due to take off, nor the proposed routes it would follow on each flight, so that people in various parts of this vast city could know when and where to look for it. Strange to say, despite B.O.A.C., we wanted to see it. And, when the aircraft did take off, it rapidly gained such an altitude that you couldn't see it properly at all. I saw the 2 p.m. take-off, and fantastic it was. It made the Boeing look like a Woollahra steam tram of long ago in comparison with a modern Bondi bus. The rate of climb of this Comet is unbelievable.

The logical idea, of course, would have been to include in the B.O.A.C. large advertisement earlier in the week full details of what the Comet 4 at Mascot was doing all the time whilst here, with full details of its movements and times of take-off and arrival. But no, we must be kept from seeing modern British jet aircraft at all costs. These blunders are simply incredible.

Sydney, N.S.W. ROBERT BARKER.

The Battle of Britain Veterans

IT is sad to read that the Air Ministry no longer finds it practicable to keep airworthy one Spitfire and one Hurricane to lead the annual Battle of Britain fly-past over London. The reason given is that the aircraft are "nearly twenty years old"! This excuse is weak in the extreme when one considers that quite small organizations, and even a few private individuals, with nothing like the technical resources of the Air Ministry at their disposal manage to keep aircraft of much older vintage flying. The Bristol Aircraft Co. even display a Bristol Fighter, built nearly 40 years ago, which still performs simple aerobatics!

The Spitfire and the Hurricane are as much a part of our heritage as Nelson's *Victory*. I want in the years to come to show my children these aircraft as I and so many others remember them—alive and in their natural element, not as dust-covered museum pieces. There is already a distressing tendency to forget Battle of Britain Day and allow it to lapse into an annual "air day," "open day," or even "flying display" as it was publicized at a local R.A.F. station.

I feel the Air Ministry should make a real effort to keep these aircraft in flying trim. They served us well and should never be forgotten.

Bodmin, Cornwall. J. EASTHOPE.

BEFORE the unfortunate crash landing of the last Spitfire on a cricket pitch is was stated that the aircraft would not actively participate in the Battle of Britain fly-past next year because it is fourteen years old and might crash on one of the vast Battle of Britain Day crowds.

In *Flight* it was stated that the average age of private aircraft on the British register is 20 years (which must make some of them nearly 30), so why should the poor old "Spit" be grounded at the comparatively tender age of fourteen?

Newbury, Berks. PATRICIA M. K. HAMMOND. (age 14).

FORTHCOMING EVENTS

Oct.	4-16.	Institute of the Aeronautical Sciences: Seventh Anglo-American Aeronautical Conference, New York and Toronto.
Oct.	9.	Helicopter Association: "The Programme of Development Testing for a Helicopter," by T. G. G. Newbery.
Oct.	13.	R.Ae.S. (Luton Branch): "Instruments and Flight Control Systems for Transport Aircraft," by W. H. McKinley.
Oct.	14.	Society of Instrument Technology: "An Automatic Analogue Computer for Missile Homing Investigations."
Oct.	21.	Brit.I.R.E. (Medical Electronics Group): "Electronic Instrumentation for Aviation Medicine," by P. V. Byford.
Oct.	22.	R.Ae.S. Astronautics and Guided Flight Section: "Problems of Interplanetary Navigation and Re-entry," by T. R. F. Nonweiler.
Oct.	27.	R.Ae.S.: "Aircraft Fatigue," by R. J. Atkinson.
Oct.	27.	Radar and Electronics Association: "Electronics in Supersonic Flight," by F. W. Page.
Oct.	28.	Brit.I.R.E. (Radar Group): "An Historical Survey of Radar and Radio Aids to Aircraft Navigation," by Air Marshal Sir Raymund G. Hart.
Oct.	28.	R.Ae.S. Graduates' and Students' Section: "Setting of Aircraft Specifications," by R. H. Whitby.
Oct.	29.	R.Ae.S.: Special General Meeting, the Society and the Helicopter Association.
Oct.	30.	R.Ae.S.: "Man-powered Aircraft, Theory and Practice," by H. B. Irving, Dr. D. R. Wilkie, T. R. F. Nonweiler and B. S. Shenstone.
Nov.	2.	Brit.I.R.E. (Liverpool Branch): "Electronics in the Autopilot of Firestreak," by A. Bedford.

XEROX